BRISTOL BAY SOCKEYE SALMON SMOLT STUDIES FOR 1996

by

Drew L. Crawford

and

Beverly A. Cross

Regional Information Report[1] No. 2A97-10

Alaska Department of Fish and Game
Division of Commercial Fisheries Management and Development
Regional Office
333 Raspberry Road
Anchorage, Alaska 99518-1599

March 1997

[1]Contribution 97-10 from the Anchorage regional office. The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate needs for up-to-date information, reports in this series may contain preliminary data.

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[a] Egegik River Smolt Project
[b] Ugashik River Smolt Project
[c] Kvichak River Smolt Project
[d] Lead Crew Member

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ABSTRACT

Numbers of sockeye salmon *Oncorhynchus nerka* smolt emigrating to sea from three rivers in Bristol Bay, Alaska, were estimated from sonar counts and age-weight-length samples from mid-May to mid-June in 1996. Hydroacoustic equipment was used to estimate total smolt biomass, and age-weight-length samples were used to convert biomass estimates into numbers of smolt by age group. Estimated numbers of smolt emigrating were 373,166,532 from Kvichak River, 31,270,793 from Egegik River, and 2,576,812 from Ugashik River. Age-1. smolt, the progeny of 1994 spawners, predominated at Kvichak River (74%) and Egegik River (71%). Age-2. smolt, the progeny of 1993 spawners, predominated at Ugashik River (56%).

KEYWORDS: smolt, sockeye salmon, *Onchorhynchus nerka*, smolt emigration, sonar, vertical distribution of passage, winter ice cover, Bristol Bay, Kvichak River, Egegik River, Ugashik River

INTRODUCTION

The Bristol Bay Management Area includes all waters east of a line from Cape Newenham to Cape Menshikof (Figure 1) and supports the largest sockeye salmon *Oncorhynchus nerka* fishery in the world. From 1976 to 1995 the commercial catch in Bristol Bay averaged 23.9 million sockeye salmon (K.Weiland, ADF&G, King Salmon, personal communication). To effectively manage this fishery, managers need accurate abundance forecasts of returning sockeye salmon and precise estimates of optimum spawning escapement goals. Estimates of outmigrating smolt numbers are currently used as an index of production for adult salmon; this improves the accuracy of preseason forecasts and aids in setting goals for optimum numbers of spawners.

Fyke nets were used to estimate smolt numbers on Kvichak River from 1956 to 1970; on Naknek River from 1956 to 1978; on Egegik River during 1957, 1969, and 1978; on Ugashik River from 1955 to 1965, 1967 to 1970, and 1972 to 1975; and on Wood River from 1955 to 1966 (Burgner and Koo 1954; Rietze and Spangler 1958; Kerns 1961; Burgner 1962; Jaenicke 1963, 1968; Church 1963; Church and Nelson 1963; Nelson 1964, 1965a, 1965b, 1966a, 1966b, 1969; Marriott 1965; Nelson and Jaenicke 1965; Pennoyer and Seibel 1965; Pennoyer 1966; Pennoyer and Stewart 1967, 1969; Robertson 1967; Siedelman 1967, 1969; Paulus and McCurdy 1969, 1972; Van Valin 1969a, 1969b; Shroeder 1972a, 1972b, 1974a; McCurdy and Paulus 1972a, 1972b; Paulus 1972; McCurdy 1974a, 1974b; Bill 1975, 1976, 1977; Pella and Jaenicke 1978; Yuen 1978). Although fyke net sampling provided information on age, size, and relative abundance of smolt, it did not provide an accurate estimate of total smolt numbers. To improve estimates of smolt numbers, the department began experimenting with and using hydroacoustic equipment.

Hydroacoustic equipment was used to estimate sockeye salmon smolt numbers on Kvichak River from 1971 through 1996; Wood River from 1975 to 1990; Naknek River from 1982 to 1986 and 1993 to 1994; Egegik River from 1982 through 1996; Ugashik River from 1983 to 1991 and 1993 to 1996; Nuyakuk River from 1983 to 1989; and Togiak River in 1988 (Russell 1972; Parker 1974a, 1974b; Krasnowski 1975; Randall 1976, 1977, 1978; Newcome 1978; Yuen 1980a, 1980b; Clark and Robertson 1980; Bucher 1980, 1981, 1982, 1983, 1984, 1986a, 1986b, 1987; Bergstrom and Yuen 1981; Yuen and Wise 1982; Eggers 1984; Eggers and Yuen 1984; Bue 1986a, 1986b; Bue and Fried 1987; Bue et al. 1988; Cross et al. 1990; Woolington et al. 1990, 1991; Crawford et al. 1992; Crawford and Cross 1992, 1994a, 1994b,1995a, 1995b, 1996).

Hydroacoustic equipment developed by Bendix Corporation[2] was tested on Kvichak River in 1969 (McCurdy and Paulus 1972b; Paulus and Parker 1974). Further testing and modification of this prototype resulted in the construction of smolt counters for use on Wood (Krasnowski 1976, 1977) and Kvichak Rivers (Randall 1977) in 1975 and 1976. Hydroacoustic equipment for counting smolt was tested on Ugashik River from 1973 to 1975 (Schroeder 1974b, 1975; Sanders 1976). Smolt studies on Naknek, Egegik, Ugashik, and Nuyakuk Rivers were limited to occasional fyke net sampling to obtain age and size data from 1975 to 1982 (Huttunen 1980; Eggers 1984; Minard

[2] Use of a company's name does not constitute endorsement.

1984). An experimental two-array sonar system similar to the one used on Kvichak River was tested on Egegik River during 1981 (Bue 1982). Smolt enumeration projects using modified counters began on Naknek and Egegik Rivers in 1982 (Huttunen 1984; Bue 1984) and on Ugashik and Nuyakuk Rivers in 1983 (Fried et al. 1987; Minard and Frederickson 1987).

Side-scanning sonar was used in 1985 and 1986 to determine the lateral distribution of smolt passing each of the respective sonar sites. Bue et al. (1988) reported that most smolt passing the Kvichak River sonar site stayed within a 68-m corridor that began 6.4 m from the left bank[3] (total river width = 100 m). Smolt passing the Egegik River sonar primarily used a 73-m corridor beginning 12.2 m from the left bank (total river width = 104 m). Ugashik River smolt used a 21-m corridor which began 7.0 m from the left bank (total river width = 43 m). Side-scanning sonar was not an effective tool for collecting lateral smolt distribution data on Wood River (Cross et al. 1990; Woolington et al. 1990, 1991). Therefore, lateral smolt distribution was assumed to be a function of river width and depth, measured and recorded when tidal influence was minimal. Based on those measurements, Wood River smolt were assumed to migrate within a 94-m corridor which began 3.3 m from the left bank.

Due to budget cuts, the monitoring of smolt migrations was discontinued on Naknek River in 1986 (Bue et al. 1988), on Togiak River in 1988 (Woolington et al. 1990), on Nuyakuk River in 1989 (Woolington et al. 1991), and on Wood River in 1990 (Crawford et al. 1992).

In 1990 a single narrow-beam, side-looking sonar unit was used from May 29 to 31 to determine the lateral limits of smolt distribution at the Kvichak River sonar site (Huttunen and Skvorc 1991); most smolt migrated between 40 and 100 m offshore from the right bank. The total river width at the site was 136 m.

The results of the 1990 study were encouraging, so in 1991 it was expanded to evaluate the feasibility of using side-looking sonar to enumerate outmigrating Kvichak River sockeye salmon smolt. Huttunen and Skvorc (1992) estimated, based on 81 h of horizontal-aspect echo-integration data collected June 2-14, that 44,972,864 smolt passed through the sonar site during the counting period. This compared well to an upward-looking sonar estimate of 43,525,980 smolt for the same hours of operation. The maximum single-beam listening range for the side-looking sonar varied from 118 m to 120 m, ensonifying 88%-90% of the total 134-m river cross section. In comparison, the three arrays of the historical upward-looking sonar ensonified roughly 7.5% of the river. The spacial distribution of smolt on a nightly basis were highly dynamic; side-looking estimates peaked at ranges from 64 m on June 12 to 118 m on June 7. Whereas the distribution of upward-looking estimates also varied between nights, the largest estimates were typically from the inshore array at 56 m from the right bank. No side-looking sonar smolt studies have been conducted since 1991 due to lack of funding.

[3] In this report the location of projects and the placement of equipment are referenced to the right and left bank of the respective river as determined by facing downstream at the study site.

Due to budget cuts, the smolt migration on Ugashik River was not monitored in 1992 (Crawford and Cross 1992). However, approval of cooperative agreements between the City of Pilot Point and ADF&G in 1993; the Lake and Peninsula Borough and ADF&G in 1994; and the City of Pilot Point, Lake and Peninsula Borough, and ADF&G in 1995; and the Lake and Peninsula Borough, and ADF&G in 1996 allowed for continued enumeration of sockeye salmon smolt with hydroacoustic equipment on Ugashik River. The Ugashik River smolt study was resumed to measure the freshwater production and the size and age structure of smolt from recent sockeye salmon spawning escapements. Also each of these organizations wanted a continuation of the historical Ugashik River sockeye salmon smolt data base that had been collected annually (except for 1992) since 1983.

In 1993, approval of a cooperative agreement between the National Park Service and the Alaska Department of Fish and Game (ADF&G) allowed for continued enumeration of sockeye salmon smolt with hydroacoustic equipment on Naknek River in 1993 and 1994. The primary impetus for resuming the Naknek River smolt study was to measure freshwater production from the record sockeye salmon escapement (3.6 million fish) that entered the Naknek River drainage to spawn during the 1991 commercial fishermen strike. This study was concluded in 1994 and was summarized in Crawford and Cross (1995b).

Upward-looking sonar studies were conducted on Kvichak, Egegik, and Ugashik Rivers in 1996 to: (1) estimate numbers of outmigrating sockeye salmon smolt; (2) describe smolt migration patterns; (3) collect smolt age, weight, and length data; and (4) record climatological and hydrological parameters which might affect migratory behavior.

METHODS

For step-by-step procedures on the installation, operation, maintenance, troubleshooting, and retrieval of smolt sonar and sampling equipment; plus detailed instructions on data collection, recording, and reporting techniques see Crawford and Tilly (1995).

Hydroacoustic Equipment

Bendix Corporation constructed all hydroacoustic systems used to estimate smolt numbers in Bristol Bay river systems in 1996; all projects used 1982 or 1983 model smolt counters. Transducers used to transmit and receive sound pulses at each sonar site were housed in two-to-three 3.03-m long arrays set on the river bottom and connected by coaxial cable to a control unit located on shore. Three arrays were used at each sonar site except Ugashik River. Only two arrays were used at Ugashik River due to a narrow channel width. Each array had 10 upward-facing single-element International Transducer Corporation[2], Model 5095 transducers which operate at a frequency of 235 Khz and a half power beamwidth angle of 9°. Detected echoes from each transducer were accumulated in the smolt counter and a printer produced a hard copy of totaled counts by array at prescribed intervals which were summed and recorded hourly on a field data collection form. Each smolt counting system was powered by a single 12-volt battery recharged by a pair of 43 watt, 2.9 amp solar panels.

Hydroacoustic equipment to monitor smolt outmigrations was operated on Kvichak, Egegik, and Ugashik Rivers from mid-May to mid-June. The smolt outmigrations in Kvichak, Egegik, and Ugashik Rivers generally peak during late May or early June and drop off by mid-June. All arrays at each project site were removed from the water at the end of the field season.

All hydroacoustic systems used in 1996 were factory calibrated to record one count whenever 41.5 g of biomass passed through each transducer beam during a given period. Because most smolt migrate within the upper portion of the water column, individual arrays were calibrated independently, which allowed the operator to set the counting range as near the surface as possible. The equipment was set to record counts to within 1-2 cm of the water surface to avoid counting debris or entrapped air.

Sources of false counts, e.g., boats, wind, rain, debris, were noted and the hydroacoustic equipment was disabled whenever false-count conditions were detected. Known false counts were subtracted from hourly totals, and linear interpolations were used to estimate counts missed while equipment was disabled. The control unit automatically recorded and stored the length of time the system was disabled. Manual control was available for adjusting printing intervals for accumulated counts, transducer pulse rate, and the portion of the water column monitored. Transducer signal characteristics were visually monitored with an oscilloscope.

Site location and equipment changes that have been made over the years to improve our ability to enumerate annual sockeye salmon smolt outmigrations using sonar are summarized in Crawford and Cross (1996).

The most recent changes were made after the 1995 smolt projects field season. Al Menin extended each of the ten center array cables (standard length = 330 ft) an additional 85 ft for use at the Kvichak River site in 1996 and he also installed 10 new 150 Uh inductors in the center array components of the smolt counter to tune them for the additional cable length. The additional cable on the center array allowed for easier deployment and better placement in the river channel.

Project Locations

The Kvichak River counting site was located 6 km below the outlet of Lake Iliamna (Figure 1); it was moved to this location in 1989, approximately 1 km downstream from the site used during the previous 15 years (Woolington et al. 1991). The Kvichak River was 129 m wide at this site. Three transducer arrays referred to as *inshore, center,* and *offshore*, were anchored 52 m, 85 m, and 100 m from the right bank (Figure 2). Array placement was improved by using lateral smolt distribution data reported by Huttunen and Skvorc (1991, 1992).

The Egegik River counting site was located 4 km below the outlet of Becharof Lake (Figure 1); it has been operated at this location since 1982 (Eggers and Yuen 1984). Egegik River is 112 m wide at this site. The inshore, center, and offshore arrays were anchored 40 m, 55 m, and 67 m from the left bank (Figure 3).

The Ugashik River counting site was located 50 m below the outlet of Lower Ugashik Lake (Figure 1). Because this river-section is only 41 m wide, only two arrays have been used. The inshore and offshore arrays were anchored 26 m and 31 m from the right bank (Figure 4).

Estimation of Smolt Numbers

The process of estimating smolt numbers was divided into three steps: (1) determining total fish biomass emigrating past the study site; (2) sampling the emigrating fish population to estimate species, age, weight, and length composition; and (3) converting fish biomass into numbers of smolt by age and species.

Biomass Estimation

Fish biomass was estimated using continually monitored hydroacoustic equipment. The signal pulse rate of the smolt counter was set to correspond with the river velocity measured at a location referred to as the *velocity index*. In most instances, the velocity at one of the arrays was used as the

velocity index. At Egegik River, a buoyed flow meter anchored downriver of the inshore array was used as the velocity index.

Estimation of River Velocities and Adjustments to Sonar Counts. River velocities at the Kvichak and Ugashik River sites were nearly constant; thus velocities were measured once a week with a Gurley[2], Model 622 flow meter and the counter was adjusted accordingly.

River velocities at the Egegik River site were influenced by tides, therefore river velocities were measured continuously by a Gurley, Model 622 or Model 625, flow meter anchored directly behind the velocity index array, and smolt counts were adjusted every 15-30 min to account for changes in river velocity. To account for differences in river velocities between the velocity index and the arrays (i), readings were taken over each array at specified intervals and velocity correction factors (vcf_i) were then calculated:

$$vcf_i = \frac{v_i}{v_{index}}, \qquad \mathbf{1}$$

where

v_i = velocity over array *i*, and
v_{index} = velocity over the velocity index array.

Adjustments to daily counts $(ac_{i,z})$ were then made for differences in river velocity:

$$ac_{i,z} = c_{i,z}(vcf_i), \qquad \mathbf{2}$$

where $c_{i,z}$ = counts for array *i* on day *z*.

Ideally, all sonar arrays monitored fish biomass 24 h/d, so daily counts for each array represented actual sonar counts. If an array was not monitored during an hour, counts were linearly interpolated using estimated counts from several hours before and after the missing count.

Expansion of Biomass Estimates. The width of the section of river $(l_{i,z})$ monitored by array *i* on day *z* depended on array length (3.03 m), water depth over the array, and transducer signal beam width:

$$l_{i,z} = 3.03 + 2\left(d_{i,z} \tan\frac{bw}{2}\right), \qquad \mathbf{3}$$

where

$d_{i,z}$ = average water depth over array i on day z, and

bw = transducer beam width in degrees (9° for all transducers).

Arrays were placed perpendicular to the river current; distances from each array to a reference point on one river bank were measured to the nearest foot. Estimates of the inshore and offshore limits of smolt passage were made based on past studies with side-scanning hydroacoustic equipment (Bue et al. 1988; Huttunen and Skvorc 1991, 1992). Distances were calculated between inshore limit of smolt passage to first array (D_1); first to second array (D_2); second to third array (D_3) at sites where three arrays were used; and offshore array to offshore limit of smolt passage (D_4).

The estimated biomass of fish ($\hat{B}_z$) passing the counting site on day z was calculated as follows:

$$\hat{B}_z = \frac{1}{2} D_1 \left(\frac{ac_{1,z}}{l_{1,z}} \right) + \sum_{i=2}^{na} \left[\frac{1}{2} D_i \left(\frac{ac_{i-1,z}}{l_{i-1,z}} + \frac{ac_{i,z}}{l_{i,z}} \right) \right] + \frac{1}{2} D_{na+1} \left(\frac{ac_{na,z}}{l_{na,z}} \right), \qquad \textbf{4}$$

where

D_i = the distance for interval i, and

na = number of transducer arrays used.

Age, Weight, and Length Estimation

Data on age, weight, and length of sockeye salmon smolt were obtained from samples captured in a fyke net. Smolt weight in grams and length, from tip-of-snout to fork-of-tail, in millimeters were measured; age was determined from visual observations of scales mounted on glass slides. European ages -- 1., 2., or 3. depending on the number of freshwater annuli -- were used. Parent year escapements that produced 1996 smolt occurred in 1994 for age-1. smolt, 1993 for age-2. smolt, and 1992 for age-3. smolt.

Sample size goals for Kvichak, Egegik, and Ugashik Rivers were 400 smolt/d. Based on binomial proportions for the two major age groups, a sample size of 400 smolt would simultaneously estimate the percentage of each age class within 5% of the true percentage 95% of the time (Goodman 1965; Cochran 1977). When the daily goal of 400 smolt was not obtained, samples from subsequent days were combined until a total of at least 400 was reached.

Mean length of smolt differs among fyke net samples from a single day (Minard and Brandt 1986). Thus, to ensure that daily age composition estimates were representative of the population, attempts were made daily to obtain 100 smolt from each of six different fyke net catches. Because weight and age of smolt are strongly correlated to length, the time and cost of data collection was reduced

by measuring all smolt collected each day: up to a maximum of 600 for length and weighing and sampling up to 100 of those smolt for age (Bue and Eggers 1989).

Age was estimated for smolt measured only for length using an age-length key (Bue and Eggers 1989). The key used length to categorize age-1. or -2. sockeye salmon smolt by determining a discriminant length that minimized classification error. This discriminant length was chosen such that the number of age-1. smolt classified as age-2. smolt was equal to the number of age-2. smolt classified as age-1. smolt. Age-3 smolt were not included in this analysis because too few samples were collected.

Weight was estimated for smolt measured only for length using a least squares linear regression. Based on paired weight-length data obtained from smolt sampled for age, weight, and length, we estimated weights (W_j) of age j smolt measured only for length as explained by (Ricker 1975):

$$W_j = \alpha L_j^{\beta} \quad , \qquad \mathbf{5}$$

where

L_j = fork length of an age j smolt, and

α and β = parameters which determine the y-axis intercept and the slope of the line.

Due to the variability of age and size composition estimates among subsamples (e.g., fyke net catches) taken the same day, daily mean weight ($\hat{W}$) and age proportions ($\hat{P}_j$) were estimated as the mean of subsampled values:

$$\hat{W} = \frac{\sum_{k=1}^{m}\left(\frac{\sum w_k}{n_k}\right)}{m} \quad , \qquad \mathbf{6}$$

where

m = number of subsamples collected during a sampling period,

w_k = observed weights from subsample k, and

n_k = number of observations in subsample k; and

$$\hat{P}_j = \frac{\sum_{k=1}^{m}\left(\frac{n_{j,k}}{n_k}\right)}{m} \quad , \qquad \mathbf{7}$$

where $n_{j,k}$ = number of observations of age j in subsample k.

Estimation of Smolt Numbers

Numbers of smolt by age were estimated by combining biomass estimates with estimates of age and weight composition. Mean weight of smolt was used to convert estimates of biomass per count into estimates of smolt per count $(\hat{SPC})$:

$$\hat{SPC} = \frac{BPC}{\hat{W}} \quad , \qquad \textbf{8}$$

where BPC = biomass (g) per count.

The estimated number of smolt passing the counting site $(\hat{N}_z)$ each day (z) was computed:

$$\hat{N}_z = \hat{B}_z \, (\hat{SPC}) \quad . \qquad \textbf{9}$$

The estimated contribution of age j smolt on day z $(\hat{N}_{j,z})$ was estimated by:

$$\hat{N}_{j,z} = \hat{N}_z (\hat{P}_j). \qquad \textbf{10}$$

Finally, daily estimates of smolt numbers were summed. The seasonal total of all smolt passing the sonar site $(\hat{N}_{tot})$ was

$$\hat{N}_{tot} = \sum \hat{N}_z \quad , \qquad \textbf{11}$$

and the estimated number of age j smolt that passed the site during the season $(\hat{N}_{jtot})$ was

$$\hat{N}_{jtot} = \sum \hat{N}_{j,z} \quad . \qquad \textbf{12}$$

Vertical Distribution of Smolt Passage

Monitoring of vertical distribution of passing smolt schools was conducted with an oscilloscope during the 2 weeks of peak smolt passage. Vertical distribution of smolt was monitored for approximately 1 h during each 8-h shift. Observers recorded the top and bottom depth (in

centimeters) of passing smolt schools and spread their hour of monitoring throughout their shift and among all arrays. The arrays that received the highest counts were monitored most.

Climatological Data Collection

Climatological data were recorded at each counting site. Observations of sky conditions and measurements of wind direction, wind velocity (km/h), daily precipitation (mm), air and water temperatures (°C) were recorded at 0800 and 2000 hours daily.

RESULTS

Kvichak River

Local residents reported that the ice began breaking up on Lake Iliamna from May 3-5 and that the lake was ice-free at Igiugig on or before May 10 (R. Russell, ADF&G retired, King Salmon, personal communication). The average reported break-up date for Lake Iliamna between 1971 and 1995 was May 15 (Appendix A.1).

ADF&G's Kvichak smolt personnel arrived in Igiugig on the evening of May 16; there was no ice in Lake Iliamna or the Kvichak River at this time. On May 17, the crew observed three instances of Arctic terns *Sterna paradisaea* catching smolt in Kvichak River. The smolt counter was activated at midnight on May 19, it immediately began registering smolt counts (e.g., 18,000 counts/h). The smolt passage rate during the first 12 h of sonar operation ranged from 3 hundred to 1.6 million smolt per hour for a total of 5.7 million smolt. Therefore an undetermined number of smolt probably passed the Kvichak smolt counting site before counting began.

The first three fyke net sets fished between 1710 and 2350 hours on May 19 caught zero sockeye salmon smolt (Appendix B.1). The fourth fyke net set fished from 2350 hours on May 19 to 0107 hours on May 20 caught 120 sockeye salmon smolt which indicated a relatively low abundance (CPUE=2) of smolt in the river. The age composition of the first fyke net catch was 15% age-1. and 85% age-2. smolt.

River velocity measurements over the center index array, which were used to adjust the sonar counter firing rate, ranged from 1.0 to 1.1 m/s (3.5 to 3.6 ft/sec). The average river velocity in 1996 was the lowest river velocity recorded at the Kvichak River sonar site in the last 10 years (Appendix C.1), however similar low flows were also observed in 1992. Velocity correction factors (m/s) used for the three arrays were as follows:

Smolt Days	Inshore	Center	Offshore
May 18 - May 26	1.01	1.00	0.91
May 27 - June 02	0.93	1.00	0.87
June 03 - June 12	0.99	1.00	0.94

A total of 11,013,989 sonar counts were recorded at the Kvichak River counting site from May 18 to June 12, 1996 (Table 1). More counts were recorded over the offshore (42%) and center (39%) arrays than over the inshore (19%) array (Figure 5). Daily sonar counts were highest from May 23 to June 1 when 90% of the total counts were recorded (Figures 6, 7). The peak daily sonar count of 2,201,333 occurred on May 28. Over the course of the entire sampling season, 34% of the total sonar counts were obtained between 1500 hours and 2100 hours and 29% occurred between 0100 hours and 0600 hours (Figure 8); the peak hourly passage rate of 288,192 sonar counts per hour occurred at 1100 hours on May 28.

Based on sonar counts an estimated 373,166,532 sockeye salmon smolt migrated from Kvichak River in 1996 (Table 2). This is the largest smolt outmigration estimate ever recorded at the Kvichak sonar site (Appendix D.1 and D.2). Age-1. smolt (1994 brood year) comprised 74% of the total smolt estimate and they predominated throughout the operation of the project. Age-2. smolt (1993 brood year) comprised the largest percentage of the daily counts from May 18 through May 21. The highest daily smolt counts occurred on May 28. Although some smolt may have passed the sonar site prior to gear deployment and were not counted, it appears that the majority passed between May 23 and June 1. Therefore, the 1996 smolt outmigration estimate for the Kvichak River should be considered a fairly good estimate. Based on trends in past outmigrations, the proportion of age-2. smolt are higher early in the season. As for the age-2. smolt, we will have to wait until the age-2.2 adults return to the Kvichak River in 1998 to find out whether the current estimate of age-2. smolt for the 1993 brood year is good or if the majority of age-2. smolt passed the sonar site prior to the start of the 1996 project. Mean weight of smolt were generally large (7.2 g to 9.1 g) throughout the season (NSC). The smolt per count estimate ranged from 4.6 to 5.8 with an average of 5.3 smolt per count (Table 3).

Total production from the 1992 spawning escapement of 4,725,864 sockeye salmon was 13.68 smolt per spawner (Table 4). The 1992 smolt production from Kvichak was 54% less than the recent ten-year average; mean production from brood years 1982-1991 was 25.21 smolt per spawner. Marine survival (i.e. adult salmon returns per smolt) has averaged 13% for age-1. smolt and 18% for age-2. smolt for the 1980-1989 brood years (Table 5).

Age, weight, and length data were collected from 1,306 sockeye salmon smolt in 1996 (Table 6). All smolt sampled were age 1. or 2. Mean length was 89 mm for age-1. smolt and 110 mm for age-2. smolt. Mean weight was 6.5 g for age-1. smolt and 11.3 g for age-2. smolt. Age-1. and -2. smolt in 1996 were 2% to 3% larger in length and 9% to 12% heavier in weight than the 1955-1995 average (Table 7). An additional 8,420 smolt were measured for length only (Table 8).

One hundred fifteen depth measurements were recorded for smolt schools passing over Kvichak River sonar arrays between May 18 and June 11 (Table 9). Schools passed at an average depth range of 22 cm to 125 cm below the surface. The water depth over the sonar arrays ranged from 269 cm to 287 cm during the peak smolt passage. Data, although limited, suggest that depth of smolt passage may have varied diurnally (Figure 9). During daylight, smolt schools tended to travel at greater depths below the surface than during darkness.

River and weather conditions were recorded at the counting site from May 17 to June 13 (Table 10). By and large the weather was excellent for counting smolt in 1996. The smolt counter was disabled for only 46 (7%) of the 612 hours it operated due to wind, waves, rain, sleet, and snow. There was no disabled time from lake ice flows in the Kvichak River or equipment problems during the 1996 Kvichak River smolt project. Mean water temperature during the project was 8.1 °C (range 5.0 °C to 13.0 °C), which was warmer (NSC) than the 1963-1995 mean of 5.8 °C (Table 11). Mean daily water temperature during the peak of the smolt migration was 7.5 °C on May 28; this is warmer than the recent 12-year average of 6.3 °C (Appendix E.1).

Egegik River

Local pilots reported that Becharof Lake was ice-free by March 28 (R. Russell, ADF&G retired, King Salmon, personal communication). Between 1975 and 1995 the earliest reported break-up date for Becharof Lake was March 31 in 1993 and the latest was May 20 in 1982 (Appendix A.2). The break-up date for 1996 is the earliest ice break-up date we have observed for Becharof Lake in the last 21 years.

The Egegik River smolt crew members flew to the study site on the afternoon and evening of May 17. There was no ice in the lake or the river when the crew arrived and no observations of smolt or birds feeding on smolt were reported prior to the startup of the Egegik River smolt sonar counter at 1200 hours on May 19. Smolt counts during the first three days of operation were low (e.g., 1,000 to 3,000 counts/d).

The first smolt catch (n=2) in the fyke net was made between 2353 hours May 21 and 0126 hours on May 22 (Appendix B.2). The crew estimated that the water level in Egegik River was about 2 ft lower than past years and boating to and from the fyke net site was difficult. The first distinct school of smolt was detected at the sonar site at 1600 hours on May 22.

River velocities at the counting site ranged from 0.2 to 0.5 m/s (0.6 to 1.5 ft/sec). These river velocities were the lowest recorded at the Egegik River sonar site in the last 12 years (Appendix C.2); the average river velocity in 1996 was 45% less than the 1984-1995 average of 0.6 m/sec (2.2 ft/sec). In 1996, the smolt counter was calibrated according to the water velocities at an index buoy set downstream from the center array. Velocity correction factors (m/s) used for three arrays were:

Smolt Days	Index Buoy	Inshore	Center	Offshore
May 19	1.00	1.00	1.36	1.29
May 20 - May 24	1.00	0.73	1.00	0.95
May 25 - May 30	1.00	0.41	0.83	0.91
May 31 - Jun 05	1.00	0.50	0.95	1.00
Jun 06 - Jun 12	1.00	0.66	0.95	1.14

A total of 2,675,965 sonar counts were recorded at the Egegik River counting site from May 19 to June 12, 1996 (Table 12). Sonar counts were most numerous over the center array (43%) followed by the inshore (34%) and offshore (23%) arrays (Figure 10). Daily sonar counts were highest from May 24-29 (Figures 11, 12). Eighty-three percent of the total sonar count was recorded during this six-day period. The peak daily sonar count of 847,312 occurred on May 24. Over the course of the season, the largest hourly sonar counts were recorded between 0100 hours and 0600 hours (Figure 13); 48% of all smolt counts were obtained during these times.

An estimated 31,270,793 sockeye salmon smolt migrated from Egegik River in 1996 based on sonar counts (Table 13). This outmigration estimate was 47% less than the 1983-1995 average for Egegik River of 58.5 million smolt (Appendix D.3 and D.4). Age -1., -2., and -3. smolt composed 71% , 26%, and 3% of the total migration respectively. The daily percentage of age-1. smolt ranged from 57% to 89% , age-2. smolt ranged from 38% to 10%, and age-3. smolt ranged from 6% to 1% during the migration. The age-3. component of the 1996 smolt outmigration is the largest we have ever documented for Egegik River. However, we will have to monitor adult returns (e.g., age 3.1, age 3.2, and age 3.3) in 1997, 1998, and 1999 to find out if there were actually more age-3. smolt this year or if the fyke net was more efficient at capturing them at low water levels. Mean weight of smolt generally decreased over the season (Table 14), resulting in an increase in the estimated number of smolt per count (NSC).

Total production from the 1992 spawning escapement of 1,945,322 sockeye salmon was 54.46 smolt per spawner (Table 15). The 1992 smolt production from Egegik was above average; mean production for brood years 1982-1991 was 46.75 smolt per spawner. Average marine survival has been 27% for age-1. smolt for the 1980-1990 brood years and 28% for age-2. smolt for the 1979-1989 brood years (Table 16).

Age, weight, and length data were collected from 854 sockeye salmon smolt in 1996 (Table 17). Age-1., -2., and -3. smolt were sampled. Mean length was 106 mm for age-1. smolt, 124 mm for age-2. smolt, and 141 mm for age-3. smolt. Mean weight was 10.5 g for age-1. smolt, 16.1 g for age-2. smolt, and 21.4 g for age-3. smolt. In comparison to the 1939-1995 average, age-1. smolt were 3% larger in length and 9% heavier in weight, age-2. smolt were 6% larger in length and 14% heavier in weight, and age-3. smolt were 7% larger in length and 6% heavier in weight (Table 18). An additional 2,136 smolt were measured for length only (Table 19).

One hundred fifty-one depth measurements were recorded for smolt schools passing over Egegik River sonar arrays during peak smolt passages between May 21 and June 10 (Table 20). Most

schools passed from 64 cm to 161 cm below the surface. Water depth over the sonar arrays at this site ranged from 262 cm to 346 cm. Figure 14 shows the depth of smolt passage by hour for each array.

River and weather conditions were recorded at the counting site from May 19 to June 13 (Table 21). The weather at Egegik River was excellent for counting smolt in 1996. The smolt counter was disabled for only 26 (4%) of the 600 hours it operated due to weather or river related events. Mean water temperature during the season was 5.8 °C (range 2.0 °C to 10.5 °C), which was slightly lower (NSC) than the 1981-1995 average of 6.5 °C (Table 22). Mean daily water temperature during the peak of the smolt outmigration on May 23 was 5.3 °C; this is slightly less then the recent 12 year average of 5.5 °C (Appendix E.2).

Ugashik River

Local pilots reported the ice on Upper and Lower Ugashik Lakes broke up by April 15 (R. Russell, ADF&G retired, King Salmon, personal communication). This is 9 d earlier than the average reported break-up date of April 23 for these lakes (Appendix A.3).

The first two Ugashik smolt crew members arrived at the study site on the evening of May 16 and the remaining crew members arrived the next morning. During the first few days, they saw several large lake trout *Salvelinus namaycush* and large Arctic char *Salvelinus alpinus* chasing schools of smolt to the surface of the water in the mainstem Ugashik River in front of camp (C. Vicary, ADF&G, Ugashik Smolt Project, personal communication). The crew also observed about 35 surf scoters *Melanitta perspicillata* feeding at the outlet of Lower Ugashik Lake at this time. The presence of these smolt predators may indicate early passage of smolt prior to the startup of the Ugashik River smolt sonar counter at 1200 hours on May 19. However the average daily water temperature when the sonar was activated this year was 4 °C (Appendix E.3), which is the temperature at which the spring overturn occurs in subarctic lakes (Goldman and Horne 1983) and is believed to be associated with the start of the annual smolt outmigration. Smolt passage was low (e.g., < 10,000 counts/d) during the first several days of operation. The first sockeye salmon smolt (n=30) were caught in the fyke net fished from 2253 hours May 20 to 0115 hours on May 21 (Appendix B.3).

River velocity measurements over the inshore index array ranged from 1.2 to 1.4 m/s (3.9 to 4.5 ft/sec). These river velocities were the second lowest recorded at the Ugashik River sonar site since 1983 (Appendix C.3); they were 32% less than the 1983-1995 average of 1.9 m/sec (6.4 ft/sec). Velocity correction factors (m/s) used to adjust the sonar counter firing rate for the two arrays were as follows:

Smolt Days	Inshore	Offshore
May 19 - May 25	1.00	0.84
May 26 - Jun 01	1.00	0.96
Jun 02 - Jun 08	1.00	0.93
Jun 09 - Jun 11	1.00	0.88

A total of 474,445 sonar counts were recorded at the Ugashik River sonar counting site from May 19 to June 11, 1996 (Table 23). Most counts (77%) were recorded over the offshore array (Figure 15). Daily sonar counts were highest from May 27 to May 30 and on June 4 when 68% of the total counts were recorded (Figures 16,17). The peak daily sonar count of 137,525 occurred on June 4. Over the entire sampling season, 67% of all smolt counts were recorded between 2400 hours and 0300 hours (Figure 18).

An estimated 2,576,812 sockeye salmon smolt migrated from Ugashik River in 1996 (Table 24). This outmigration estimate was 97% less than the 1983-1995 average for Ugashik River of 75.8 million smolt and it is the smallest Ugashik River smolt outmigration estimate on record (Appendices D.5, D.6 and F). Due to the extremely low 1996 Ugashik River smolt outmigration estimate, this number will be treated as a preliminary estimate until we can evaluate the strength of the adult salmon returns from these smolt. The dominant age groups of adult sockeye salmon from the 1996 smolt outmigration will return in 1998 (ages 1.2 and 2.2 fish) and 1999 (ages 1.3 and 2.3 fish).

Age-2. smolt (1993 brood year) composed 56% of the total migration (Table 24). Age-1. smolt (1994 brood year) were less numerous prior to June 3 (26% to 47%) and more thereafter (57% to 82%) as the outmigration progressed. The estimated number of smolt per sonar count ranged from 3.1 to 4.5 (Table 25).

The total smolt production of age-1. and -2. smolt from the 1992 spawning escapement of 2,173,692 sockeye salmon was 39,577,888 smolt; this equates to a smolt per spawner value of 18.21 (Table 26). Marine survival has averaged 7% for age-1. smolt for the 1981-89 brood years and 12% for age-2. smolt for the 1980-88 brood years (Table 27).

Age, weight, and length data were collected from 1,506 sockeye salmon smolt in 1996 (Table 28). Mean length was 101 mm for age-1. smolt and 114 mm for age-2. smolt. Mean weight was 9.9 g for age-1. smolt and 13.5 g for age-2. smolt. Age-1. smolt were 15% larger than the 1958-1995 average length and 50% heavier; age-2. smolt were 6% larger and 16% heavier than average (Table 29). An additional 8,175 sockeye salmon smolt were sampled for length only (Table 30).

Eleven depth measurements were recorded for smolt schools passing over Ugashik River sonar arrays between May 24 and June 10 (Table 31). Schools passed at an average depth of 8 cm to 62 cm below the surface. Water depth over the sonar arrays at this site ranged from 268 cm to 294 cm during the peak smolt passage. Figure 19 shows the depth of smolt passage by hour for each array.

River and weather conditions were recorded at the counting site from May 19 to June 12 (Table 32). The weather was fair-to-good for enumerating sockeye salmon smolt emigrating from Upper and Lower Ugashik Lakes in 1996. High winds caused 93% of the 109 h of disabled time this year, followed by snow, waves action, and rain. Seventy hours of this disable time were estimated by interpolation (Table 23). An additional 39 h of weather related disable time were not estimated by interpolation. For comparison, the Ugashik River smolt counter was disabled on one or more arrays for 264 h in 1993 due to weather-related events and 162 h of these counts were adjusted by interpolation. Average water temperature was 5.6 °C (range 3.0 °C to 7.5 °C), which was slightly cooler (NSC) than the 1983-95 average of 6.1 °C (Table 33). The mean water temperature during the peak of the smolt outmigration -- June 4 -- was 7.0 °C; this is 1.1 °C warmer then the 1984-1995 average of 5.9 °C (Appendix E.3).

LITERATURE CITED

Bergstrom, D.J., and H.J. Yuen. 1981. 1980 Kvichak River sockeye salmon smolt studies. Pages 1-15 *in* C.P. Meacham, editor. 1980 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 63, Juneau.

Bill, D.L. 1975. 1974 Naknek River sockeye salmon smolt studies. Pages 14-23 *in* P. Krasnowski, editor. 1974 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 20, Juneau.

Bill, D.L. 1976. 1975 Naknek River sockeye salmon smolt studies. Pages 10-19 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.

Bill, D.L. 1977. 1976 Naknek River sockeye salmon smolt studies. Pages 14-23 *in* N. Newcome, editor. 1976 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 33, Juneau.

Bucher, W. 1980. 1979 Wood River sockeye salmon smolt studies. Pages 12-33 *in* C.P. Meacham, editor. 1979 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 46, Juneau.

Bucher, W. 1981. 1980 Wood River sockeye salmon smolt studies. Pages 16-33 *in* C.P. Meacham, editor. 1980 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 63, Juneau.

Bucher, W. 1982. 1981 Wood River sockeye salmon smolt studies. Pages 28-48 *in* D.C. Huttunen, editor. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 73, Juneau.

Bucher, W. 1983. 1983 Wood River sockeye salmon smolt studies. Pages 72-96 *in* B.G. Bue, and S.M Fried, editors. 1987. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.

Bucher, W. 1984. 1982 Wood River sockeye salmon smolt studies. Pages 47-68 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

LITERATURE CITED (Continued)

Bucher, W. 1986a. 1984 Wood River sockeye salmon smolt studies. Pages 56-78 *in* B.G. Bue, editor. 1984 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 182, Juneau.

Bucher, W. 1986b. 1985 Wood River sockeye salmon smolt studies. Pages 67-91 *in* B.G. Bue, editor. 1985 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 184, Juneau.

Bucher, W. 1987. 1983 Wood River sockeye salmon smolt studies. Pages 72-98 *in* B.G. Bue, and S.M. Fried, editors. 1987. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.

Bue, B.G. 1982. 1981 Egegik River sockeye salmon smolt studies. Pages 15-27 *in* D.C. Huttunen, editor. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 73, Juneau.

Bue, B.G. 1984. 1982 Egegik River sockeye salmon smolt studies. Pages 28-40 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

Bue, B.G. editor. 1986a. 1984 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 182, Juneau.

Bue, B.G. editor. 1986b. 1985 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 184, Juneau.

Bue, B.G., and D.M. Eggers. 1989. An age-length key for sockeye salmon. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2D89-5, Anchorage.

Bue, B.G., and S.M. Fried. 1987. Bristol Bay sockeye salmon smolt studies for 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.

Bue, B.G., D.L. Bill, W.A. Bucher, S.M. Fried, H.J. Yuen, and R.E. Minard. 1988. Bristol Bay sockeye salmon smolt studies for 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 88-15, Juneau.

LITERATURE CITED (Continued)

Burgner, R.L. 1962. Studies of red salmon smolts from the Wood River Lakes, Alaska. Pages 251-314 *in* T.S.Y. Koo, editor. Studies of Alaska Red Salmon. University of Washington Publications in Fisheries, Seattle.

Burgner, R.L., and S.Y. Koo. 1954. Results of the red salmon seaward migrant enumeration, Wood River Lakes, 1951-1953. University of Washington, Fisheries Research Institute, Circular 62, Seattle.

Church, W. 1963. Red salmon smolts from the Wood River system, 1961. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 32, Juneau.

Church, W., and M. Nelson. 1963. Abundance, size and age of red salmon smolts from the Wood River system, 1962. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 33, Juneau.

Clark, J.H., and T.L. Robertson. 1980. 1978 Wood River sockeye salmon smolt studies. Pages 18-29 *in* C.P. Meacham, editor. 1978 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 44, Juneau.

Cochran, W.G. 1977. Sampling Techniques. John Wiley and Sons, New York, New York.

Crawford, D.L., and B.A. Cross. 1992. Bristol Bay sockeye salmon smolt studies for 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 92-20, Juneau.

Crawford, D.L., and B.A. Cross. 1994a. Bristol Bay sockeye salmon smolt studies for 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Technical Fisheries Report 94-19, Juneau.

Crawford, D.L., and B.A. Cross. 1994b. Bristol Bay sockeye salmon smolt studies for 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A94-14, Anchorage.

Crawford, D.L., and B.A. Cross. 1995a. Bristol Bay sockeye salmon smolt studies for 1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A95-12, Anchorage.

Crawford, D.L., and B.A. Cross. 1995b. Naknek River sockeye salmon smolt studies 1993-1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A95-09, Anchorage.

LITERATURE CITED (Continued)

Crawford, D.L., and B.A. Cross. 1996. Bristol Bay sockeye salmon smolt studies for 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A96-10, Anchorage.

Crawford, D.L., and F.C. Tilly. 1995. Bristol Bay upward-looking sonar sockeye salmon smolt enumeration project instruction manual. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A95-14, Anchorage.

Crawford, D.L., J.D. Woolington, and B.A. Cross. 1992. Bristol Bay sockeye salmon smolt studies for 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 91-2013, Juneau.

Cross, B.A., B.L.Stratton, and B.G. Bue. 1990. Bristol Bay sockeye salmon smolt studies for 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 90-05, Juneau.

Eggers, D.M. 1984. 1982 Ugashik River sockeye salmon smolt studies. Pages 41-46 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

Eggers, D.M., and H.J. Yuen, editors. 1984. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

Fried, S.M., H.J. Yuen, and B.G. Bue. 1987. 1983 Naknek, Egegik, and Ugashik rivers sockeye salmon smolt studies. Pages 36-71 *in* B.G. Bue, and S.M. Fried, editors. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.

Goldman, C.R., and A.J. Horne. 1983. Limnology. McGraw-Hill Book Company. New York.

Goodman, L. 1965. On simultaneous confidence intervals from multinomial populations. Technometrics. 7:247-254.

Huttunen, D.C. 1980. 1978 Bristol Bay special sockeye salmon smolt studies. Pages 30-34 *in* C.P. Meacham, editor. 1978 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 44, Juneau.

LITERATURE CITED (Continued)

Huttunen, D.C. 1984. 1982 Naknek River sockeye salmon smolt studies. Pages 14-27 *in* D.G. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

Huttunen, D.C., and P.A. Skvorc II, 1991. Kvichak River side-looking sonar smolt investigations, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J91-04, Anchorage.

Huttunen, D.C., and P.A. Skvorc II, 1992. Kvichak River side-looking sonar abundance estimation. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J92-07, Anchorage.

Jaenicke, H.W. 1963. Ugashik River smolt studies: a preliminary report of the 1962 season. United States Department of the Interior, Bureau of Commercial Fisheries, Manuscript Report 63-5, Auke Bay, Alaska.

Jaenicke, H.W. 1968. Sockeye salmon smolt investigations on the Ugashik River, Alaska, 1958-63. Master of Science Thesis, Humbolt State College, Humbolt, California.

Kerns, O.E. 1961. Abundance and age of Kvichak River red salmon smolts. Fishery Bulletin 189(61):301-320.

Krasnowski, P. 1975. 1974 Kvichak River sockeye salmon smolt studies. Pages 1-13 *in* P. Krasnowski, editor. 1974 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 20, Juneau.

Krasnowski, P. 1976. 1975 Wood River sockeye salmon smolt studies. Pages 29-51 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.

Krasnowski, P. 1977. 1976 Wood River sockeye salmon smolt studies. Pages 24-43 *in* N. Newcome, editor. 1976 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 33, Juneau.

Marriott, R.A. 1965. 1963 Kvichak River red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 48, Juneau.

LITERATURE CITED (Continued)

McCurdy, M.L., and R.D. Paulus. 1972a. 1971 Naknek River sockeye salmon smolt studies. Pages 29-34 *in* P.A. Russell, and M.L. McCurdy, editors. 1971 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 2, Juneau.

McCurdy, M.L., and R.D. Paulus. 1972b. 1969 Kvichak River sockeye salmon smolt studies. Pages 1-34 *in* M.L. McCurdy, editor. 1969 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 3, Juneau.

McCurdy, M.L. 1974a. 1972 Naknek River sockeye salmon smolt studies. Pages 38-48 *in* K.P. Parker, editor. 1972 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 13, Juneau.

McCurdy, M.L. 1974b. 1973 Naknek River sockeye salmon smolt studies. Pages 23-32 *in* K.P. Parker, editor. 1973 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 14, Juneau.

Minard, R.E. 1984. 1982 Nushagak and Nuyakuk River sockeye salmon smolt studies. Pages 69-72 *in* D.M. Eggers, and H.J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

Minard, R.E., and J. Brandt. 1986. 1985 Nuyakuk River sockeye salmon smolt studies. Pages 92-106 *in* B.G. Bue, editor. 1985 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 184, Juneau.

Minard, R.E., and M. Frederickson. 1987. 1983 Nuyakuk River sockeye salmon smolt studies. Pages 97-110 *in* B.G. Bue, and S.M. Fried, editors. 1983 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.

National Weather Service. 1995. 1995 Local climatological data, annual summary with comparative data, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9787.

National Weather Service. 1996a. Local climatological data, monthly summary, January 1996, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (1 of 12).

LITERATURE CITED (Continued)

National Weather Service. 1996b. Local climatological data, monthly summary, February 1996, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (2 of 12).

National Weather Service. 1996c. Local climatological data, monthly summary, March 1996, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (3 of 12).

National Weather Service. 1996d. Local climatological data, monthly summary, April 1996, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (4 of 12).

National Weather Service. 1996e. Local climatological data, monthly summary, May 1996, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (5 of 12).

National Weather Service. 1996f. Local climatological data, monthly summary, June 1996, King Salmon, Alaska. National Oceanic and Atmospheric Administration, National Climatic Data Center, ISSN 0197-9795 (6 of 12).

Nelson, M.L. 1964. Abundance, size and age of red salmon smolts from the Wood River system, 1963. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 37, Juneau.

Nelson, M.L. 1965a. Abundance, size, age and survival of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1964. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 62, Juneau.

Nelson, M.L. 1965b. Abundance, size and age of red salmon smolts from the Wood River system, 1964. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 54, Juneau.

Nelson, M.L. 1966a. Abundance, size, age and survival of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1965. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 85, Juneau.

Nelson, M.L. 1966b. Abundance, size and age of red salmon smolts from the Wood River Lakes system, 1965. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 76, Juneau.

LITERATURE CITED (Continued)

Nelson, M.L. 1969. 1967 Ugashik River red salmon smolt studies. Pages 26-32 *in* D.M. Stewart, editor. 1967 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 134, Juneau.

Nelson, M.L., and H.W. Jaenicke. 1965. Abundance, size and age of red salmon smolts from the Ugashik Lakes system, Bristol Bay, 1963. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 49, Juneau.

Newcome, N. 1978. 1977 Wood River sockeye salmon studies. Pages 24-34 *in* H. Yuen, editor. 1977 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 41, Juneau.

Parker, K.P. 1974a. 1972 Kvichak River sockeye salmon smolt studies. Pages 1-37 *in* K.P. Parker editor. 1972 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 13, Juneau.

Parker, K.P. 1974b. 1973 Kvichak River sockeye salmon smolt studies. Pages 1-22 *in* K.P. Parker, editor. 1973 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 14, Juneau.

Paulus, R.D. 1972. 1969 Egegik River sockeye salmon smolt studies. Pages 62-65 *in* M.L. McCurdy, editor. 1969 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 3, Juneau.

Paulus, R., and M. McCurdy. 1969. 1968 Kvichak River sockeye salmon (*Oncorhynchus nerka*) smolt studies. Pages 1-45 *in* M.L. McCurdy, editor. 1968 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 138, Juneau.

Paulus, R.D., and M.L. McCurdy. 1972. 1970 Kvichak River sockeye salmon smolt studies. Pages 1-13 *in* P.A. Russell, editor. 1970 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 4, Juneau.

Paulus, R., and K. Parker. 1974. Kvichak River sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 166, Juneau.

LITERATURE CITED (Continued)

Pella, J.J., and H.W. Jaenicke. 1978. Some observations on the biology and variations of populations of sockeye salmon of the Naknek and Ugashik Systems of Bristol Bay, Alaska. National Oceanic and Atmospheric Administration, Northwest Fisheries Center, Northwest and Alaska Fisheries Center Processed Report, Seattle, Washington.

Pennoyer, S. 1966. 1965 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 83, Juneau.

Pennoyer, S., and M.C. Seibel. 1965. 1964 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 58, Juneau.

Pennoyer, S., and D.M. Stewart. 1967. 1966 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Pages 4-18 *in* D.M. Stewart, editor. 1966 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 102, Juneau.

Pennoyer, S., and D.M. Stewart. 1969. 1967 Kvichak River red salmon (*Oncorhynchus nerka*) smolt studies. Pages 4-17 *in* D.M. Stewart, editor. 1967 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 134, Juneau.

Randall, R.C. 1976. 1975 Kvichak River sockeye salmon smolt studies. Pages 1-9 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.

Randall, R.C. 1977. 1976 Kvichak River sockeye salmon smolt studies. Pages 1-13 *in* N. Newcome, editor. 1976 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 33, Juneau.

Randall, R.C. 1978. 1977 Kvichak River sockeye salmon smolt studies. Pages 1-5 *in* H. Yuen, editor. 1977 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 41, Juneau

Rietze, H.L., and P.J. Spangler. 1958. Operation report for red salmon smolt studies on the Naknek and Egegik Rivers, 1957. United States Fish and Wildlife Service, Bureau of Commercial Fisheries, Western Alaska Salmon Investigations.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191, Ottawa, Canada.

LITERATURE CITED (Continued)

Robertson, A.D. 1967. Naknek River red salmon smolt study, 1966. Pages 34-40 *in* D.M. Stewart, editor. 1966 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 102, Juneau.

Russell, P.A. 1972. 1971 Kvichak River sockeye salmon smolt studies. Pages 1-28 *in* P.A. Russell, and M.L. McCurdy, editors. 1971 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 2, Juneau.

Sanders, G.H. 1976. 1975 Ugashik River sockeye salmon smolt studies. Pages 20-28 *in* P. Krasnowski, editor. 1975 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 25, Juneau.

Schroeder, T.R. 1972a. 1969 Ugashik River sockeye salmon smolt studies. Pages 35-45 *in* M.L. McCurdy, editor. 1969 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 3, Juneau.

Schroeder, T.R. 1972b. 1970 Ugashik River sockeye salmon smolt studies. Pages 14-23 *in* P.A. Russell, editor. 1970 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 4, Juneau.

Schroeder, T.R. 1974a. 1972 Ugashik River sockeye salmon smolt studies. Pages 49-56 *in* K.P. Parker, editor. 1972 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 13, Juneau.

Schroeder, T.R. 1974b. 1973 Ugashik River sockeye salmon smolt studies. Pages 33-45 *in* K.P. Parker, editor. 1973 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 14, Juneau.

Schroeder, T.R. 1975. 1974 Ugashik River sockeye salmon smolt studies. Pages 24-37 *in* P. Krasnowski, editor. 1974 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 20, Juneau.

Siedelman, D.L. 1967. Abundance, size and age of red salmon smolts from the Wood River Lakes system, 1966. Pages 18-33 *in* D.M. Stewart, editor. 1966 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 102, Juneau.

LITERATURE CITED (Continued)

Siedelman, D.L. 1969. Abundance, size and age of sockeye salmon smolt from the Ugashik Lakes system, 1968. Pages 46-61 *in* M.L. McCurdy, editor. 1968 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 138, Juneau.

Van Valin, G.R. 1969a. Naknek River red salmon smolt study, 1967. Pages 33-43 *in* D.M. Stewart, editor. 1967 Bristol Bay red salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 134, Juneau.

Van Valin, G.R. 1969b. Naknek River sockeye salmon smolt study, 1968. Pages 62-77 *in* M.L. McCurdy, editor. 1968 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 138, Juneau.

Woolington, J.D., B.A. Cross, B.L. Stratton, and B.G. Bue. 1990. Bristol Bay sockeye salmon smolt studies for 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 90-16, Juneau.

Woolington, J.D., B.A. Cross, and B.L. Stratton. 1991. Bristol Bay sockeye salmon smolt studies for 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report 91-19, Juneau.

Yuen, H.J. 1978. 1977 Naknek River sockeye salmon smolt studies. Pages 12-23 *in* H. Yuen, editor. 1977 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 41, Juneau.

Yuen, H.J. 1980a. 1978 Kvichak River sockeye salmon smolt studies. Pages 1-17 *in* C.P. Meacham, editor. 1978 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 44, Juneau.

Yuen, H.J. 1980b. 1979 Kvichak River sockeye salmon smolt studies. Pages 1-12 *in* C.P. Meacham, editor. 1979 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 46, Juneau.

Yuen, H.J., and M. Wise. 1982. 1981 Kvichak River sockeye salmon smolt studies. Pages 2-15 *in* D.C. Huttunen, editor. 1981 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 73, Juneau.

Table 1. Sonar counts recorded from three arrays at the sockeye salmon smolt counting site on Kvichak River, 1996.

Smolt Day [a]		Sonar Count by Transducer Array			
		Inshore	Center	Offshore	Total
5/18		9,638	88,460	124,888	222,986
5/19		2,590	5,343	2,712	10,645
5/20	[b]	11,753	30,034	12,346	54,133
5/21	[b]	12,298	26,426	14,736	53,460
5/22	[b]	16,152	29,833	28,750	74,735
5/23	[b]	95,271	140,051	168,655	403,977
5/24		218,800	457,185	641,673	1,317,658
5/25	[b]	101,115	82,303	50,006	233,424
5/26		282,051	549,785	307,201	1,139,037
5/27	[c]	280,285	718,060	884,785	1,883,130
5/28		526,516	913,706	761,111	2,201,333
5/29		130,272	263,112	320,985	714,369
5/30		119,358	433,972	594,073	1,147,403
5/31		99,165	145,396	260,284	504,845
6/01		43,377	96,008	202,215	341,600
6/02		21,434	23,808	28,011	73,253
6/03	[b]	13,227	17,583	22,267	53,077
6/04	[b]	5,534	10,791	5,677	22,002
6/05		6,120	6,707	2,127	14,954
6/06		7,358	14,035	6,084	27,477
6/07		6,718	2,127	445	9,290
6/08		20,918	16,183	17,061	54,162
6/09		33,958	81,483	77,086	192,527
6/10	[b]	15,028	42,045	57,362	114,435
6/11		12,141	24,410	44,165	80,716
6/12		17,105	34,531	17,725	69,361
Total		2,108,182	4,253,377	4,652,430	11,013,989
Percent		19.14	38.62	42.24	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

[b] Data interpolated for one or more arrays for the following time periods:

1200-1900 hours on May 20 due to SE wind and rain
0800-0900 hours on May 21 (Smolt Day - May 20) due to snow and rain
2300 hours on May 21 due to sleet
2100-2300 hours on May 22 due to NE wind and large waves with white caps
0500-1100 hours on May 23 (Smolt Day - May 22) due to E wind and entrained air
1200-2100 hours on May 23 due to ENE wind and entrained air
2200 hours on May 25 due to hard rain
1200-1800 hours on June 3 due to NW wind and standing waves
1400-1700 hours on June 4 due to NW wind and large waves
1800 hours on June 10 due to waves
0600-0700 hours on June 11 (Smolt Day - June 10) due to heavy snow

[c] From 0705-0845 hours on May 28 (Smolt Day - May 27) the crew visually observed large numbers of smolt passing near the surface beyond the counting range of the offshore array by the left bank.

Table 2. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Kvichak River, 1996.

	Age 1.			Age 2.			All Ages	
Smolt Day [a]	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/18	3,041,803	53.8	3,041,803	2,610,005	46.2	2,610,005	5,651,808	5,651,808
5/19	182,775	53.8	3,224,578	156,829	46.2	2,766,834	339,604	5,991,412
5/20	925,822	53.8	4,150,400	794,397	46.2	3,561,231	1,720,219	7,711,631
5/21	901,682	53.8	5,052,082	773,684	46.2	4,334,915	1,675,366	9,386,997
5/22	2,092,603	75.8	7,144,685	667,723	24.2	5,002,638	2,760,326	12,147,323
5/23	11,200,353	75.8	18,345,038	3,573,889	24.2	8,576,527	14,774,242	26,921,565
5/24	34,359,081	75.8	52,704,119	10,963,542	24.2	19,540,069	45,322,623	72,244,188
5/25	7,605,533	75.8	60,309,652	2,426,828	24.2	21,966,897	10,032,361	82,276,549
5/26	22,375,936	58.0	82,685,588	16,209,916	42.0	38,176,813	38,585,852	120,862,401
5/27	49,338,819	78.2	132,024,407	13,738,167	21.8	51,914,980	63,076,986	183,939,387
5/28	60,518,729	77.0	192,543,136	18,026,020	23.0	69,941,000	78,544,749	262,484,136
5/29	15,367,473	69.2	207,910,609	6,836,649	30.8	76,777,649	22,204,122	284,688,258
5/30	29,441,312	80.1	237,351,921	7,318,972	19.9	84,096,621	36,760,284	321,448,542
5/31	13,735,960	79.6	251,087,881	3,511,604	20.4	87,608,225	17,247,564	338,696,106
6/01	7,813,015	76.9	258,900,896	2,344,310	23.1	89,952,535	10,157,325	348,853,431
6/02	2,083,678	79.0	260,984,574	552,554	21.0	90,505,089	2,636,232	351,489,663
6/03	1,510,131	78.2	262,494,705	421,971	21.8	90,927,060	1,932,102	353,421,765
6/04	659,493	78.2	263,154,198	184,280	21.8	91,111,340	843,773	354,265,538
6/05	465,589	76.2	263,619,787	145,821	23.8	91,257,161	611,410	354,876,948
6/06	785,475	76.2	264,405,262	246,008	23.8	91,503,169	1,031,483	355,908,431
6/07	336,620	76.2	264,741,882	105,428	23.8	91,608,597	442,048	356,350,479
6/08	1,259,072	65.8	266,000,954	655,575	34.2	92,264,172	1,914,647	358,265,126
6/09	4,455,681	71.6	270,456,635	1,767,337	28.4	94,031,509	6,223,018	364,488,144
6/10	2,616,539	72.3	273,073,174	1,001,963	27.7	95,033,472	3,618,502	368,106,646
6/11	1,839,112	72.3	274,912,286	704,259	27.7	95,737,731	2,543,371	370,650,017
6/12	1,819,692	72.3	276,731,978	696,823	27.7	96,434,554	2,516,515	373,166,532
	276,731,978	74.2		96,434,554	25.8		373,166,532	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 3. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Kvichak River, 1996.

Smolt Day [a]	Mean Weight of Smolt (g)	Smolt per Count
5/18	9.1	4.6
5/19	9.1	4.6
5/20	9.1	4.6
5/21	9.1	4.6
5/22	7.4	5.6
5/23	7.4	5.6
5/24	7.4	5.6
5/25	7.4	5.6
5/26	8.5	4.9
5/27	7.3	5.7
5/28	7.5	5.6
5/29	8.0	5.2
5/30	7.3	5.7
5/31	7.2	5.8
6/01	7.7	5.4
6/02	7.5	5.5
6/03	7.6	5.5
6/04	7.6	5.5
6/05	7.8	5.3
6/06	7.8	5.3
6/07	7.8	5.3
6/08	8.5	4.9
6/09	8.2	5.1
6/10	7.9	5.3
6/11	7.9	5.3
6/12	7.9	5.3

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 4. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1956-1994. brood years, Kvichak River

Brood Year	Total Spawning Escapement	Number of Smolt Produced							
		Age 1.	(%)[a]	Age 2.	(%)[a]	Age 3.	(%)[a]	Total	Per Spawner
		Estimates of smolt numbers based upon fyke net catches							
1956	9,443,318	3,267,274	54	2,777,960	46	0		6,045,234	0.64
1957	2,842,810	85,916	13	552,603	87	0		638,519	0.22
1958	534,785	61,400	86	10,126	14	0		71,526	0.13
1959	680,000	26,038	27	72,180	73	0		98,218	0.14
1960	14,630,000	1,130,820	22	4,116,093	78	0		5,246,913	0.36
1961	3,705,849	113,338	7	1,603,464	93	0		1,716,802	0.46
1962	2,580,884	458,122	21	1,748,178	79	0		2,206,300	0.85
1963	338,760	64,377	73	23,377	27	0		87,754	0.26
1964	957,120	252,384	53	222,528	47	0		474,912	0.50
1965	24,325,926	2,866,214	34	5,475,362	66	0		8,341,576	0.34
1966	3,775,184	648,321	55	541,017	45	0		1,189,338	0.32
1967	3,216,208	594,327	67	298,282	33	0		892,609	0.28
1968	2,557,440	185,356							
		Estimates of smolt numbers based upon hydroacoustic techniques							
1968				5,959,383		0		-	-
1969	8,394,204	85,723,430	61	54,159,340	39	0		139,882,770	16.66
1970	13,935,306	464,219	<1	191,842,930	98	2,918,768	1	195,225,917	14.01
1971	2,387,392	5,123,400	19	21,423,246	81	0		26,546,646	11.12
1972	1,009,962	2,740,610		-		-		-	-
1973	226,554	-		3,031,287		0		-	-
1974	4,433,844	108,356,892	49	114,269,848	51	0		222,626,740	50.21
1975	13,140,450	78,308,251	27	213,364,470	73	0		291,672,721	22.20
1976	1,965,282	32,226,544	55	26,423,348	45	0		58,649,892	29.84
1977	1,341,144	28,758,191	73	10,410,467	27	0		39,168,658	29.21
1978	4,149,288	182,442,540	85	32,294,536	15	0		214,737,076	51.75
1979	11,218,434	219,928,232	71	89,300,703	29	0		309,228,935	27.56
1980	17,505,268	150,421,026	66	76,244,773	34	0		226,665,799	12.95
1981	1,754,358	6,549,125	15	37,595,987	85	0		44,145,112	25.16
1982	1,134,840	51,893,988	96	1,937,408	4	2,065	<1	53,833,461	47.44
1983	3,569,982	23,590,443	31	53,260,693	69	123,975	<1	76,975,111	21.56
1984	10,490,670	83,470,460	20	331,384,545	80	43,135	<1	414,898,140	39.55
1985	7,211,046	11,178,398	11	87,004,194	89	30,345	<1	98,212,937	13.62
1986	1,179,322	13,126,363	66	6,830,717	34	0		19,957,080	16.92
1987	6,065,880	146,603,154	78	41,434,534	22	0		188,037,688	31.00
1988	4,065,216	46,569,569	58	34,266,421	42	0		80,835,990	19.88
1989	8,317,500	87,187,761	59	61,317,308	41	0		148,505,069	17.85
1990	6,970,020	18,172,700	8	204,626,879	92	0		222,799,579	31.97
1991	4,222,788	21,781,009	42	30,207,268	58	0		51,988,277	12.31
1992	4,725,864	53,638,204	83	11,034,144	17	0		64,672,348	13.68
1993	4,025,166	209,857,983	69	96,434,554	31			306,292,537	76.09 [b]
1994	9,571,245	276,731,978							[b]
Max 82-91	10,490,670	146,603,154	96	331,384,545	92	123,975		414,898,140	47.44
Avg 82-91	5,322,726	50,357,385	47	85,226,997	53	19,952		135,604,333	25.21
Min 82-91	1,134,840	11,178,398	8	1,937,408	4	0		19,957,080	12.31

[a] Percent of total smolt production.

[b] Preliminary total. Incomplete returns from brood year escapements.

Table 5. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1952-1994 brood years, Kvichak River.

Brood Year	Total Spawning Escapement	Age 1. Number of Smolt	Age 1. Adult Returns [a]	Age 1. Adult Returns per Smolt	Age 2. Number of Smolt	Age 2. Adult Returns [a]	Age 2. Adult Returns per Smolt
		Estimates of smolt numbers based upon fyke net catches.					
1952	-	-			241,870	3,610,258	[b]
1953	-	18,198	152,165	[b]	47,373	424,627	[b]
1954	-	30,287	109,965	[b]	8,654	659,246	[b]
1955	-	22,253	351,240	[b]	66,679	1,132,813	[b]
1956	9,443,318	3,267,274	31,253,977	[b]	2,777,960	7,773,131	[b]
1957	2,842,810	85,916	488,844	[b]	552,603	3,591,552	[b]
1958	534,785	61,400	124,250	[b]	10,126	161,253	[b]
1959	680,000	26,038	328,287	[b]	72,180	217,593	[b]
1960	14,630,000	1,130,820	1,877,221	[b]	4,116,093	53,360,190	[b]
1961	3,705,849	113,338	524,416	[b]	1,603,464	2,971,816	[b]
1962	2,580,884	458,122	256,253	0.56	1,748,178	5,083,162	[b]
1963	338,760	64,377	98,571	[b]	23,377	1,008,242	[b]
1964	957,120	252,384	2,647,042	[b]	222,528	3,093,042	[b]
1965	24,325,926	2,866,214	10,349,415	[b]	5,475,362	34,671,692	[b]
1966	3,775,184	648,321	1,594,186	[b]	541,017	4,657,432	[b]
1967	3,216,208	594,327	621,690	[b]	298,282	900,307	[b]
1968	2,557,440	185,356	332,177	[b]	-		
		Estimates of smolt numbers based upon hydroacoustic techniques					
1968	2,557,440	-			5,959,383	209,138	0.04
1969	8,394,204	85,723,430	449,791	0.01	54,159,340	4,824,026	0.09
1970	13,935,306	464,219	56,778	0.12	191,842,930	15,351,498	0.08
1971	2,387,392	5,123,400	337,314	0.07	21,423,246	2,489,981	0.12
1972	1,009,962	2,740,610	436,837	0.16	-	1,504,435	[b]
1973	226,554	-	1,606,766	[b]	3,031,287	818,529	0.27
1974	4,433,844	108,356,892	8,353,542	0.08	114,269,848	17,796,617	0.16
1975	13,140,450	78,308,251	6,920,452	0.09	213,364,470	31,164,576	0.15
1976	1,965,282	32,226,544	6,132,390	0.19	26,423,348	4,431,284	0.17
1977	1,341,144	28,758,191	2,912,441	0.10	10,410,467	309,369	0.03
1978	4,149,288	182,442,540	2,991,655	0.02	32,294,536	2,151,024	0.07
1979	11,218,434	219,928,232	20,621,724	0.09	89,300,703	21,516,038	0.24
1980	22,505,268	150,421,026	4,534,253	0.03	76,244,773	8,508,770	0.11
1981	1,754,358	6,549,125	1,019,361	0.16	37,595,987	1,098,376	0.03
1982	1,134,840	51,893,988	995,144	0.02	1,937,408	663,241	0.34
1983	3,569,982	23,590,443	11,612,066	0.49	53,260,693	1,773,436	0.03
1984	10,490,670	83,470,460	4,455,429	0.05	331,384,545	19,441,947	0.06
1985	7,211,046	11,178,398	2,311,147	0.21	87,004,194	14,991,491	0.17
1986	1,179,322	13,126,363	1,804,257	0.14	6,830,717	2,721,114	0.40
1987	6,065,880	146,603,154	6,710,655	0.05	41,434,534	5,217,874	0.13
1988	4,065,216	46,569,569	4,979,438	0.11	34,266,421	4,901,646	0.14
1989	8,317,500	87,187,761	3,802,200	0.04	61,317,308	22,236,773	0.36
1990	6,970,020	18,172,700	2,728,898	0.15	204,626,879	22,507,925 [c]	0.11 [c]
1991	4,222,788	21,781,009	3,954,299 [c]	0.18 [c]	30,207,268	705,762 [c]	
1992	4,725,864	53,638,204	422,170 [c]		11,034,144	2,025 [c]	
1993	4,025,166	209,857,983	948 [c]		96,434,554		
1994	9,571,245	276,731,978					
Max 80-8	22,505,268	150,421,026	11,612,066	0.49	331,384,545	22,236,773	0.40
Avg 80-89	6,629,408	62,059,029	4,222,395	0.13	73,127,658	8,155,467	0.18
Min 80-89	1,134,840	6,549,125	995,144	0.02	1,937,408	663,241	0.03

[a] Includes estimates of returns through 1996.

[b] Insufficient smolt samples collected to perform this calculation.

[c] Future adult returns will increase these values.

Table 6. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Kvichak River, 1996.

	Age 1.					Age 2.				
Smolt Day [a]	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/19					0	113	8.4	12.2	2.62	19
5/20	94	23.8	7.7	6.01	32	104	22.9	10.8	6.46	18
5/21	86	11.1	6.1	2.44	26	110	6.1	12.7	2.99	14
5/25	86	12.7	5.3	2.39	91	107	9.3	9.5	2.67	8
5/26	89	12.9	6.4	2.50	48	111	13.1	11.4	4.09	52
5/27	83	15.9	6.0	3.07	91	107	13.8	10.7	3.88	9
5/28	87	11.1	6.4	2.60	93	109	9.8	11.4	3.18	7
5/29	85	14.6	6.4	3.28	68	114	13.7	12.6	3.64	31
5/30	87	12.1	6.7	2.90	85	108	13.7	10.6	3.33	15
5/31	85	13.3	6.4	3.07	86	108	18.5	11.1	4.15	14
6/01	87	13.2	6.5	3.12	91	110	9.2	11.7	4.33	8
6/02	88	12.4	6.7	3.46	95	103	4.9	10.5	0.90	5
6/03					0					0
6/04	88	10.3	6.9	2.04	37	114	2.7	12.2	1.83	3
6/05	93	10.8	6.7	2.11	18	111	4.8	10.9	0.65	2
6/06	91	11.7	6.7	1.95	32	112	14.0	11.4	3.92	8
6/07	89	11.7	6.1	1.97	17	116	5.9	12.7	1.56	3
6/08	94	4.6	7.3	1.14	12	114	4.1	12.4	1.33	8
6/09	88	16.7	6.6	2.71	80	108	12.8	11.7	3.73	20
6/10	91	10.9	6.2	2.29	37	109	5.4	10.2	0.79	3
6/11	92	8.4	6.5	2.23	18	112	3.0	10.0		2
Total					1,057					249
Mean	89		6.5			110		11.3		

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 7. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Kvichak River, 1955-1996.

	Age 1.				Age 2.				Age 3.				
Year of Migration	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Total Estimate [a]
1955	1953	7	89	_	1952	93	_	_	1951	0	_	_	260,068
1956	1954	39	92	_	1953	61	116	_	1952	0	_	_	77,660
1957	1955	72	96	7.3	1954	28	120	14.4	1953	0	_	_	30,907
1958	1956	98	84	4.6	1955	2	114	_	1954	0	_	_	3,333,953
1959	1957	3	80	_	1956	97	99	7.6	1955	0	_	_	2,863,876
1960	1958	10	91	6.3	1957	90	108	10.3	1956	0	_	_	614,003
1961	1959	72	92	6.8	1958	28	117	13.1	1957	0	_	_	36,164
1962	1960	94	82	4.3	1959	6	110	9.9	1958	0	_	_	1,203,000
1963	1961	3	83	4.8	1960	97	98	7.5	1959	0	_	_	4,229,431
1964	1962	22	87	5.2	1961	78	108	9.8	1960	0	_	_	2,061,586
1965	1963	4	90	6.8	1962	96	109	11.3	1961	0	_	_	1,812,555
1966	1964	92	94	7.4	1963	8	114	12.6	1962	0	_	_	275,761
1967	1965	93	86	5.9	1964	7	118	14.2	1963	0	_	_	3,088,742
1968	1966	11	88	5.5	1965	89	104	9.2	1964	0	_	_	6,123,683
1969	1967	52	92	5.7	1966	48	109	10.6	1965	0	_	_	1,135,344
1970	1968	38	91	6.0	1967	62	110	11.0	1966	0	_	_	483,638
1971	1969	93	90	5.8	1968	7	111	11.1	1967	0	_	_	91,682,813
1972	1970	1	80	4.2	1969	99	106	10.0	1968	0	_	_	54,623,559
1973	1971	3	86	5.1	1970	97	97	8.3	1969	0	_	_	196,966,331
1974	1972	9	96	8.3	1971	79	111	13.1	1970	12	124	17.5	27,082,626
1975	1973	63	98	8.4	1972	37	122	16.4	1971	0	_	_	15,632,531
1976	1974	97	88	5.8	1973	3	121	14.2	1972	0	_	_	111,388,180
1977	1975	38	86	5.5	1974	62	106	10.1	1973	0	_	_	192,578,099
1978	1976	12	88	6.0	1975	88	97	7.8	1974	0	_	_	245,591,014
1979	1977	51	90	6.0	1976	49	109	10.3	1975	0	_	_	55,181,540
1980	1978	94	88	5.9	1977	6	110	10.7	1976	0	_	_	192,853,007
1981	1979	89	85	5.4	1978	11	108	10.2	1977	0	_	_	252,222,769
1982	1980	58	84	5.1	1979	39	103	9.1	1978	0	_	_	239,721,729
1983	1981	8	80	4.9	1980	92	98	8.5	1979	0	_	_	82,793,899
1984	1982	58	90	6.8	1981	42	104	10.0	1980	0	_	_	89,489,975
1985	1983	92	85	5.3	1982	8	102	9.2	1981	0	_	_	25,527,851
1986	1984	61	84	5.5	1983	39	107	10.4	1982	<1	102	9.1	136,733,218
1987	1985	3	82	4.5	1984	97	96	7.0	1983	<1	97	8.5	342,686,918
1988	1986	13	86	5.6	1985	87	99	8.3	1984	<1	107	9.8	100,173,692
1989	1987	95	85	5.5	1986	5	108	10.8	1985	<1	105	9.5	153,464,216
1990	1988	53	87	6.1	1987	47	105	10.5	1986	0	_	_	88,004,103
1991	1989	72	85	5.5	1988	28	105	9.9	1987	0	_	_	121,454,182
1992	1990	23	84	5.6	1989	77	100	9.3	1988	0	_	_	79,490,008
1993	1991	10	86	6.0	1990	90	97	8.2	1989	0	_	_	226,407,888
1994	1992	64	84	5.7	1991	36	102	9.5	1990	0	_	_	83,845,472
1995	1993	95	87	6.2	1992	5	103	9.8	1991	0	_	_	220,892,127
Mean			87	5.8			107	10.4			107	10.9	
1996	1994	74	89	6.5	1993	26	110	11.3	1992	0	_	_	373,166,532
% Difference			2	12			3	9					

[a] Estimates of smolt numbers from 1955 to 1970 based on fyke net catches; estimates of smolt numbers from 1971 to 1995 based on hydroacoustic techniques.

Table 8. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Kvichak River, 1996.

	Estimated Age 1. [a]				Estimated Age 2. [a]			
Smolt Day [b]	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size
5/19	91	10.0	6.8	28	113	18.2	12.2	128
5/20	89	11.3	6.5	92	112	12.6	11.9	61
5/21	88	12.9	6.4	131	110	11.6	11.4	41
5/25	86	20.1	6.1	563	111	15.2	11.7	71
5/26	85	18.7	6.1	442	111	15.0	11.6	133
5/27	85	24.0	6.0	493	107	17.3	10.8	48
5/28	86	19.6	6.2	479	107	12.8	10.7	58
5/29	86	17.8	6.1	440	113	16.2	12.3	92
5/30	86	19.2	6.1	594	108	10.9	11.1	37
5/31	84	22.5	5.9	571	106	12.2	10.6	33
6/01	87	22.3	6.3	551	111	15.4	11.6	66
6/02	87	21.8	6.3	664	110	14.8	11.5	62
6/03	84	16.0	6.0	43	102		9.4	1
6/04	88	20.8	6.4	335	105	5.4	10.2	6
6/05	90	6.0	6.7	13				0
6/06	89	17.7	6.6	262	110	14.4	11.4	42
6/07	88	17.1	6.5	134	110	9.5	11.4	12
6/08	90	19.1	6.8	413	109	14.9	11.2	82
6/09	90	19.2	6.8	574	109	18.9	11.3	95
6/10	87	20.3	6.4	271	105	6.8	10.2	11
6/11	91	12.2	6.9	171	110	15.0	11.5	77
Total				7,264				1,156
Mean	88		6.4		109		11.2	

[a] Length-weight parameters by age group and discriminating length used to separate ages from May 19 to June 11 were:

Age 1. a = -6.7627 b = 1.8233 r^2 = 0.4593 n = 1,057
Age 2. a = -8.8258 b = 2.3933 r^2 = 0.7220 n = 249

Discriminating Length = 99.63 mm

[b] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 9. Depth of sockeye salmon smolt passage at Kvichak River sonar site, May 18 to June 11, 1996.

	Depth of Passage (cm)							
	Inshore Array [a] Smolt Schools		Center Array [b] Smolt Schools		Offshore Array [c] Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Minimum	1	30	0	44	0	55	0	30
Mean	26	128	21	126	18	120	22	125
Maximum	58	162	70	163	80	190	80	190
n	18	18	45	45	52	52	115	115

[a] Average depth of inshore array on smolt day 5/28 was 277 cm.

[b] Average depth of center array on smolt day 5/28 was 269 cm.

[c] Average deph of offshore array on smolt day 5/28 was 287 cm.

Table 10. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Kvichak River, 1996.

Date	Cloud Cover [a]		Wind [b] Direction & Velocity (km/h)		Air Temperature (°C)		Water Temperature (°C)		Percipitation (mm)	Water Clarity [c]
	0800	2000	0800	2000	0800	2000	0800	2000		
5/17	1	1	-	-	-	-	7	8	0.00	clear
5/18	2	1	-	SW 24	-	-	7	-	trace	clear
5/19	3	3	SE 08	SE 16	-	10.0	8.0	9.0	0.00	clear
5/20	4	3	SE 24	S 24	4.0	5.0	6.0	7.0	trace	clear
5/21	4	3	0	NE 16	1.0	6.0	5.0	8.0	0.24	clear
5/22	2	3	0	NE 24	-3.0	10.5	5.0	8.0	0.06	clear
5/23	4	2	E 48-72	E 64 +	6.0	10.5	5.0	8.5	0.00	murky
5/24	4	2	NE 16-24	SE 24-32	5.0	11.0	5.0	8.5	0.00	murky
5/25	4	3	0	E 08	4.0	10.0	5.5	7.5	trace	murky
5/26	2	4	0	E 05	2.0	10.0	5.5	8.0	0.27	clear
5/27	4	4	SE 08	0	6.0	10.0	6.0	7.5	0.06	clear
5/28	2	2	0	E 08	10.0	13.0	6.0	9.0	0.12	clear
5/29	2	2	SE 08	N 24	8.0	16.0	6.0	10.0	0.00	murky
5/30	1	1	0	N 08	12.0	17.5	7.0	10.5	0.00	clear
5/31	1	2	0	SW 0-08	8.0	19.0	8.0	10.5	0.00	clear
6/01	1	1	0	SW 13-19	11.0	23.0	9.0	12.0	0.00	clear
6/02	4	1	0	W 13	13.0	23.0	10.0	12.5	0.00	clear
6/03	4	1	0	WNW 16-29	10.0	23.0	10.0	12.5	0.00	clear
6/04	1	1	0	NW 24	15.0	22.0	9.0	13.0	0.00	clear
6/05	1	1	0	0	10.0	24.0	9.0	11.5	0.00	clear
6/06	1	2	NW 08	S 11	8.0	21.0	8.0	11.5	0.00	clear
6/07	4	4	W 0-08	S 16-24	7.0	10.5	8.0	9.0	0.12	clear
6/08	4	3	SW 5-13	S 08	5.0	13.5	6.0	9.0	0.48	clear
6/09	3	3	0	SW 11	9.0	13.0	7.0	9.0	0.13	clear
6/10	4	3	W 13-19	SW 16	5.0	13.0	6.0	8.5	0.00	clear
6/11	4	4	SW 8-16	SW 24	-1.0	11.0	5.0	9.0	0.20	clear
6/12	3	2	SW 0-08	0	6.0	17	6.0	10	0.00	clear
6/13	3	-	E 11	-	8.0	-	8.0	-	-	clear

[a] 1 = Cloud cover not more than 1/10
2 = Cloud cover not more than 1/2
3 = Cloud cover more than 1/2
4 = Completely overcast
5 = Fog

[b] var. = variable winds

[c] Water clarity at 0800 hours

Table 11. Water temperatures at sockeye salmon smolt counting site, Kvichak River, 1963-1996.

		Water Temperature (°C)		
Year	Sample Period	Minimum	Mean	Maximum
1963	May 16 - June 14	2.2	5.5	8.9
1964	May 18 - June 14	0.0	2.6	5.6
1965	May 17 - June 11	0.0	4.4	8.9
1966	May 16 - June 26	0.0	4.7	11.1
1967	May 17 - June 20	1.1	6.9	9.4
1968	May 12 - June 12	3.3	5.4	8.3
1969	May 16 - June 18	0.3	3.9	7.8
1970	May 13 - June 07	2.8	6.8	11.1
1971	May 17 - June 20	1.1	2.4	3.3
1972	May 18 - June 18	0.6	2.9	5.0
1973	May 15 - June 14	2.9	4.9	8.9
1974	May 13 - June 09	3.0	6.2	8.0
1975	May 17 - June 15	2.0	3.8	8.0
1976	May 18 - June 19	2.0	3.9	9.5
1977	May 17 - June 14	3.0	6.4	9.5
1978	May 19 - June 09	5.0	7.6	11.0
1979	June 01 - June 10	8.0	8.6	10.0
1980	May 16 - June 18	1.5	5.5	9.0
1981	May 15 - June 09	7.0	8.2	10.0
1982	May 14 - June 15	2.5	4.9	8.5
1983	May 19 - June 14	5.2	7.9	10.5
1984	May 19 - June 11	5.5	7.9	10.0
1985	May 23 - June 20	2.0	4.6	7.0
1986	May 18 - June 12	1.0	4.6	7.0
1987	May 21 - June 13	4.5	6.7	9.0
1988	May 17 - June 17	3.0	7.1	11.0
1989	May 19 - June 16	3.0	5.8	8.8
1990	May 22 - June 15	3.5	7.3	9.5
1991	May 23 - June 17	1.0	4.8	8.5
1992	May 22 - June 14	5.0	7.8	10.0
1993	May 19 - June 12	4.0	6.6	11.0
1994	May 22 - June 16	1.5	6.1	11.0
1995	May 21 - June 14	4.0	8.1	12.5
	Mean	2.8	5.8	9.0
1996	May 17 - June 13	5.0	8.1	13.0

Table 12. Sonar counts recorded from three arrays at the sockeye salmon smolt counting site on Egegik River, 1996.

Smolt Day [a]		Sonar Count: Transducer Array: Inshore	Center	Offshore	Total
5/19	[b]	63	130	1,019	1,212
5/20		174	2,889	1,009	4,072
5/21		1,623	6,532	3,000	11,155
5/22	[c]	35,022	36,699	19,550	91,271
5/23	[d]	25,143	25,158	23,298	73,599
5/24		216,383	508,157	122,772	847,312
5/25		217,654	222,525	93,688	533,867
5/26		92,273	72,251	194,822	359,346
5/27		135,297	49,479	11,678	196,454
5/28		43,242	51,954	17,222	112,418
5/29	[e]	97,450	66,699	28,905	193,054
5/30		4,133	19,521	7,069	30,723
5/31		3,496	7,815	9,770	21,081
6/01		12,493	23,816	12,451	48,760
6/02	[d]	621	10,472	2,431	13,524
6/03		1,023	2,345	3,907	7,275
6/04	[d]	3,417	7,565	5,976	16,958
6/05		7,308	3,847	2,330	13,485
6/06		6,906	5,644	17,416	29,966
6/07	[d]	1,748	6,617	9,212	17,577
6/08	[d]	624	9,225	9,055	18,904
6/09	[d]	1,154	5,691	5,993	12,838
6/10	[d]	1,381	4,008	5,953	11,342
6/11	[d]	419	1,170	1,663	3,252
6/12		1,350	2,784	2,386	6,520
Total		910,397	1,152,993	612,575	2,675,965
Percent		34.0	43.1	22.9	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

[b] The sonar counter was activated at 1200 hours on May 19.

[c] First reported schools of smolt begin passing the smolt counter at 1600 hours on May 22.

[d] Sonar counts interpolated for one or more arrays on the following hours and dates:

1300-1700 hours on May 23 due to wind SE 20-55
0800-0900 hours on June 3 (smolt day-June 2) due to river velocity < 1 ft/sec
1400-2000 hours on June 4 due to wind and wave action
0800 and 1000-1100 on June 5 (smolt day-June 4) due to a flow meter problem
1000-1100 hours on June 8 (smolt day-June 7) due to river velocity < 1 ft/sec
1100-1200 hours June 9 (smolt days-June 8 & 9) due to river velocity < 1 ft/sec
2400 hours June 9 to 0100 hours June 10 due to river velocity < 1 ft/sec
1200-1300 hours on June 10 due to river velocity < 1 ft/sec
0100-0200 hours on June 11 (smolt day-June 10) due to river velocity < 1 ft/sec
0300-0400 hours on June 12 (smolt day-June 11) due to river velocity < 1 ft/sec

[e] Reported visual sighting of several smolt schools passing the sonar site near the surface of the water at 2200 hours on May 29. Sighting confirmed by corresponding sonar counts registered on the center and offshore arrays.

Table 13. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Egegik River, 1996.

	Age 1.			Age 2.			Age 3.			All Ages	
Smolt Day [a]	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/19	11,729	56.7	11,729	7,763	37.5	7,763	1,197	5.8	1,197	20,689	20,689
5/20	26,479	56.7	38,208	17,525	37.5	25,288	2,704	5.8	3,901	46,708	67,397
5/21	74,720	56.7	112,928	49,453	37.5	74,741	7,631	5.8	11,532	131,804	199,201
5/22	635,500	56.7	748,428	420,602	37.5	495,343	64,906	5.8	76,438	1,121,008	1,320,209
5/23	521,051	56.7	1,269,479	344,855	37.5	840,198	53,217	5.8	129,655	919,123	2,239,332
5/24	5,693,610	56.7	6,963,089	3,768,288	37.5	4,608,486	581,513	5.8	711,168	10,043,411	12,282,743
5/25	2,727,601	56.7	9,690,690	1,805,249	37.5	6,413,735	278,582	5.8	989,750	4,811,432	17,094,175
5/26	4,368,246	88.3	14,058,936	552,767	11.2	6,966,502	23,237	0.5	1,012,987	4,944,250	22,038,425
5/27	1,878,385	88.3	15,937,321	237,694	11.2	7,204,196	9,992	0.5	1,022,979	2,126,071	24,164,496
5/28	915,974	77.5	16,853,295	259,224	21.9	7,463,420	6,855	0.6	1,029,834	1,182,053	25,346,549
5/29	1,967,214	88.8	18,820,509	238,926	10.8	7,702,346	8,193	0.4	1,038,027	2,214,333	27,560,882
5/30	334,500	88.8	19,155,009	39,344	10.4	7,741,690	3,014	0.8	1,041,041	376,858	27,937,740
5/31	274,796	88.8	19,429,805	32,321	10.4	7,774,011	2,476	0.8	1,043,517	309,593	28,247,333
6/01	593,783	88.8	20,023,588	69,841	10.4	7,843,852	5,351	0.8	1,048,868	668,975	28,916,308
6/02	166,179	88.8	20,189,767	19,546	10.4	7,863,398	1,497	0.8	1,050,365	187,222	29,103,530
6/03	96,967	88.8	20,286,734	11,405	10.4	7,874,803	873	0.8	1,051,238	109,245	29,212,775
6/04	214,020	88.8	20,500,754	25,173	10.4	7,899,976	1,928	0.8	1,053,166	241,121	29,453,896
6/05	152,805	88.8	20,653,559	17,973	10.4	7,917,949	1,377	0.8	1,054,543	172,155	29,626,051
6/06	452,326	88.8	21,105,885	53,202	10.4	7,971,151	4,076	0.8	1,058,619	509,604	30,135,655
6/07	254,923	88.8	21,360,808	29,984	10.4	8,001,135	2,297	0.8	1,060,916	287,204	30,422,859
6/08	267,533	88.8	21,628,341	31,467	10.4	8,032,602	2,411	0.8	1,063,327	301,411	30,724,270
6/09	181,429	88.8	21,809,770	21,339	10.4	8,053,941	1,635	0.8	1,064,962	204,403	30,928,673
6/10	165,150	88.8	21,974,920	19,425	10.4	8,073,366	1,488	0.8	1,066,450	186,063	31,114,736
6/11	47,468	88.8	22,022,388	5,583	10.4	8,078,949	427	0.8	1,066,877	53,478	31,168,214
6/12	91,050	88.8	22,113,438	10,709	10.4	8,089,658	820	0.8	1,067,697	102,579	31,270,793
	22,113,438	70.7		8,089,658	25.9		1,067,697	3.4		31,270,793	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 14. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Egegik River, 1996.

Smolt Day [a]	Mean Weight of Smolt (g)	Smolt per Count
5/19	13.8	3.0
5/20	13.8	3.0
5/21	13.8	3.0
5/22	13.8	3.0
5/23	13.8	3.0
5/24	13.8	3.0
5/25	13.8	3.0
5/26	10.5	4.0
5/27	10.5	4.0
5/28	12.0	3.5
5/29	10.6	3.9
5/30	10.9	3.8
5/31	10.9	3.8
6/01	10.9	3.8
6/02	10.9	3.8
6/03	10.9	3.8
6/04	10.9	3.8
6/05	10.9	3.8
6/06	10.9	3.8
6/07	10.9	3.8
6/08	10.9	3.8
6/09	10.9	3.8
6/10	10.9	3.8
6/11	10.9	3.8
6/12	10.9	3.8

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day

Table 15. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by age class, and number of smolt produced per spawner for 1978-1994 brood years, Egegik River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced							
		Age 1.	(%[a])	Age 2.	(%[a])	Age 3.	(%[a])	Total	Per Spawner
1978	895,698					225,522			
1979	1,032,042			14,287,075		0			
1980	1,060,860	49,457,563	75	16,524,563	25	197,429	0	66,179,555	62.38
1981	694,680	2,242,326	6	32,235,734	93	52,852	0	34,530,912	49.71
1982	1,034,628	17,234,269	60	11,434,848	40	564	0	28,669,681	27.71
1983	792,282	54,585,828	64	29,984,140	35	85,087	0	84,655,055	106.85 [b]
1984	1,165,320	14,016,441	24	45,386,536	76	80,931	0	59,483,908	51.05
1985	1,095,192	4,397,087	26	12,758,135	74	81,150	0	17,236,372	15.74
1986	1,151,320	36,122,149	57	27,347,612	43	0	0	63,469,761	55.13
1987	1,272,978	72,458,024	58	52,299,487	42	396,423	0	125,153,934	98.32 [b]
1988	1,612,680	3,795,739	4	89,162,038	96	361,128	0	93,318,905	57.87
1989	1,610,916	4,519,527	21	17,338,786	79	37,254	0	21,895,567	13.59
1990	2,191,362	6,048,364	14	37,719,609	86	19,196	0	43,787,169	19.98
1991	2,786,880	20,203,545	34	39,158,743	66	11,242	0	59,373,530	21.30
1992	1,945,332	54,909,050	52	49,962,265	47	1,067,697	1	105,939,012	54.46
1993	1,516,980	7,412,283	48	8,089,658	52			15,501,941 [c]	10.22 [c]
1994	1,897,932	22,113,438							
Max 82-91	2,786,880	72,458,024	64	89,162,038	96	396,423	0	125,153,934	106.85
Avg 82-91	1,471,356	23,338,097	36	36,258,993	64	107,298	0	59,704,388	46.75
Min 82-91	792,282	3,795,739	4	11,434,848	35	0	0	17,236,372	13.59

[a] Percent of total smolt production

[b] Smolt outmigration estimates for brood years with unusually high smolt per spawner ratios may be artifically low. During these years smolt may have passed undetected before, during, or after the operational dates of the smolt sonar.

[c] Preliminary total

Table 16. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1978-1994 brood years, Egegik River.

		Age 1.			Age 2.			Age 3.		
Brood Year	Total Spawning Escapement	Number of Smolt	Adult [a] Returns	Adult Returns per Smolt	Number of Smolt	Adult [a] Returns	Adult Returns per Smolt	Number of Smolt	Adult [a] Returns	Adult Returns per Smolt
1978	895,698		908,379			8,264,740		225,522	33,395	0.15
1979	1,032,042		1,239,273		14,287,075	4,705,018	0.33	0	0	
1980	1,060,860	49,457,563	3,035,494	0.06	16,524,563	5,519,025	0.33	197,429	7,730	0.04
1981	694,680	2,242,326	1,508,516	0.67	32,235,734	4,785,803	0.15	52,852	16,119	0.30
1982	1,034,628	17,234,269	2,873,325	0.17	11,434,848	3,447,534	0.30	564	12,739	[b]
1983	792,282	54,585,828	4,520,747	0.08	30,036,716	6,085,720	0.20	85,087	37,329	0.44
1984	1,165,320	14,160,585	1,596,859	0.11	45,386,536	11,482,531	0.25	80,931	249,131	[b]
1985	1,095,192	4,397,087	1,951,334	0.44	12,758,135	558,244	0.04	81,150	26,295	0.32
1986	1,151,320	36,122,149	5,664,220	0.16	27,347,612	8,549,130	0.31	0	116,845	[b]
1987	1,272,978	72,458,024	5,550,526	0.08	52,299,487	20,140,758	0.39	396,423	201,328	0.51
1988	1,612,680	3,795,739	1,910,599	0.50	89,162,038	16,780,162	0.19	361,128	411,139	[b]
1989	1,610,916	4,519,527	1,065,313	0.24	17,338,786	10,137,718	0.58	37,245	195,314 [c]	[b]
1990	2,191,362	6,048,364	1,279,028	0.21	37,719,609	14,393,793 [c]	0.38 [c]	19,196	21,075 [c]	
1991	2,786,880	20,203,545	5,330,068 [c]	0.26 [c]	39,158,743	3,155,015 [c]		11,242	0 [c]	
1992	1,945,332	54,909,050	336,937 [c]		49,962,265	55,068 [c]		1,067,697		
1993	1,516,980	7,412,283	1,639 [c]		8,089,658					
1994	1,897,932	22,113,438								
Max	2,786,880	72,458,024	5,664,220	0.67	89,162,038	20,140,758	0.58	396,423	411,139	0.51
Avg	1,397,475	21,556,390	2,792,047	0.27	33,452,446	8,748,663	0.28	125,556	107,866	0.32
Min	694,680	2,242,326	1,065,313	0.08	11,434,848	558,244	0.04	0	0	0.04

a Includes estimates fo returns through 1996.

[b] Insufficient age-3. smolt sampled to perform this calculation.

[c] Future adult returns will increase these values.

Table 17. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Egegik River, 1996.

	Age 1.					Age 2.					Age 3.				
Smolt Day [a]	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/21	109	1.8	10.5	0.06	2					0					0
5/22	120	14.9	15.2	5.89	2	128	13.8	17.1	6.07	5	142	8.7	20.2	0.21	3
5/24	105	1.8	9.9	0.06	2	124	16.0	15.8	5.64	9	146		20.6		1
5/25	107	11.4	11.3	6.14	61	129	25.8	18.2	9.84	36	140	6.5	22.8	3.63	3
5/26	101	15.6	9.4	4.81	74	116	23.5	13.4	8.13	18	143	1.8	22.6	0.77	2
5/27	101	15.3	9.2	4.21	88	125	19.3	14.6	3.80	10	143	3.0	23.0	2.20	2
5/28	105	13.5	10.5	4.95	72	126	23.4	17.2	9.37	24	139	10.0	22.6	5.81	4
5/29	102	14.1	10.3	4.68	76	122	22.5	15.9	9.07	21	135	11.8	16.3	3.63	3
5/30	105	13.8	9.7	3.95	44	122	18.4	15.6	7.34	8					0
5/31	106	11.4	11.0	3.71	16	122	10.5	15.7	3.16	5	145		24.2		1
6/01	102	12.8	9.5	3.62	37	136		22.5		1					0
6/02	107	12.5	10.6	3.52	17	130	9.1	17.3	4.64	6	140		20.9		1
6/03	111	7.4	13.4	2.80	6	117		15.4		1					0
6/04	108	13.9	10.6	3.11	22	131		19.3		1					0
6/05	102	13.2	9.7	4.07	10	122	5.7	14.1	2.58	3					0
6/06	108	14.2	10.9	4.52	13	119		13.5		1					0
6/07	98	1.1	7.7	0.22	3					0					0
6/08	102	7.9	9.1	2.53	8	120		13.8		1					0
6/09	109	16.7	11.2	5.35	64	124	15.3	15.4	4.60	13	137	5.9	21.3	2.26	2
6/10	106	14.5	10.9	5.31	48	118	5.9	14.1	2.97	2					0
6/11	108	4.8	9.1	1.37	2					0					0
Total					667					165					22
Mean	106		10.5			124		16.1			141		21.4		

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 18. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Egegik River, 1939-1996.

	Age 1.				Age 2.				Age 3.				
Year of Migration	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Total Estimate [a]
1939	1937		96		1936		105		1935				
1956	1954		101		1953		116		1952		123		
1957	1955		107		1954		120		1953		130		
1959	1957		99		1956		116		1955		123		
1960	1958		106		1957		115		1956		140		
1969	1967		99		1966		119		1965		115		
1977	1975		110	11.3	1974		116	13.3	1973				
1978	1976		104	10.1	1975		122	15.4	1974		130	18.1	
1981	1979		105	9.1	1978		122	16.6	1977		128	19.1	
1982	1980	77	104	9.2	1979	23	130	17.1	1978	0	145	23.5	63,970,160
1983	1981	12	101	9.3	1980	88	116	13.6	1979	0			18,766,889
1984	1982	35	106	10.1	1981	65	112	12.2	1980	0	134	20.2	49,667,432
1985	1983	83	106	10.4	1982	17	123	16.8	1981	0	138	24.1	66,073,548
1986	1984	32	101	9.0	1983	68	122	15.7	1982	0	140	22.6	44,197,865
1987	1985	9	107	11.6	1984	91	114	14.1	1983	0	128	18.9	49,868,710
1988	1986	74	103	10.2	1985	26	117	14.3	1984	0	136	21.2	48,961,215
1989	1987	73	99	8.9	1986	27	119	15.4	1985	0	135	21.1	99,886,786
1990	1988	7	87	6.1	1987	93	105	10.5	1986	0			56,095,226
1991	1989	5	102	10.3	1988	95	118	15.6	1987	0	140	24.4	94,095,226
1992	1990	26	104	10.2	1989	73	112	12.4	1988	1	127	17.6	23,748,278
1993	1991	35	102	9.3	1990	65	112	12.2	1989	0	138	22.1	57,960,399
1994	1992	58	104	9.6	1991	42	118	13.7	1990	0	125	14.6	94,086,989
1995	1993	13	103	9.3	1992	87	112	11.6	1991	0	126	14.9	57,385,790
Mean			102	9.6			117	14.1			132	20.2	
1996	1994	71	106	10.5	1993	26	124	16.1	1992	3	141	21.4	31,270,793
% Difference			3	9			6	14			7	6	

[a] No estimate of smolt numbers for 1939-1981 fyke net catches; estimates of smolt numbers from 1982-1996 based on hydroacoustic techniques.

Table 19. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Egegik River, 1996.

	Estimated Age 1. [a]				Estimated Age 2. [a]			
Smolt Day [b]	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size
5/25	106	20.9	10.5	334	129	32.1	17.8	168
5/26	102	12.4	9.5	52	131	13.0	18.2	7
5/27	102	27.4	9.6	628	128	28.2	17.3	75
5/28	104	22.4	10.0	371	131	31.9	18.3	131
5/29	102	20.8	9.6	326	125	23.8	16.3	44
Total				1,711				425
Mean	103		9.9		129		17.6	

[a] Length-weight parameters by age group and discriminating length used to separate ages from May 25 to May 29 were:

Age 1. $a = -10.3313$ $b = 2.7176$ $r^2 = 0.7093$ $n = 667$
Age 2. $a = -9.8984$ $b = 2.6239$ $r^2 = 0.8206$ $n = 163$

Discriminating Length = 115.23 mm

[b] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 20. Depth of sockeye salmon smolt passage at Egegik River sonar site, May 21 to June 10, 1996.

	Depth of Passage (cm)							
	Inshore Array [a]		Center Array [b]		Offshore Array [c]		All Combined	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Maximum	109	176	106	240	110	248	110	248
Average	64	139	60	160	69	184	64	161
Minimum	0	85	5	32	16	112	0	32
n	41	41	63	63	47	47	151	151

[a] Average depth of inshore array on smolt day 5/24 was 262 cm.

[b] Average depth of center array on smolt day 5/24 was 307 cm.

[c] Average depth of offshore array on smolt day 5/24 was 346 cm.

Table 21. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Egegik River, 1996.

Date	Cloud Cover [a]		Wind [b] Direction & Velocity (km/h)		Air Temperature (°C)		Water Temperature (°C)		Percipitation (mm)	Water Clarity [c]
	0800	2000	0800	2000	0800	2000	0800	2000		
5/19	1	5	NW 16	NW 20	-	6.0	3.5	6.0	0.00	clear
5/20	4	2	W 16	SW 24-32	3.3	6.7	4.0	7.0	0.02	clear
5/21	2	3	S 08	SE 24-32	1.1	3.3	2.0	7.0	0.03	clear
5/22	2	4	SE 40	E 40-48	2.8	7.2	2.5	5.0	0.02	clear
5/23	3	3	SE 08	SE 40-48	6.9	6.7	3.0	6.0	0.00	clear
5/24	2	3	SE 56	SE 40	5.8	7.8	3.5	7.0	0.02	clear
5/25	4	3	SE 08	SE 24	4.7	7.5	4.0	6.0	0.02	clear
5/26	4	3	SE 32	SE 24	4.7	10.0	4.5	5.5	0.04	clear
5/27	4	3	SE 16	SE 16-24	5.3	6.0	4.0	5.5	0.10	clear
5/28	1	3	SE 40	SE 40-48	6.1	5.8	4.5	5.0	0.00	clear
5/29	2	2	SE 08	0	6.1	11.0	4.0	5.5	0.00	clear
5/30	1	1	0	NW 16	6.1	16.5	3.5	9.0	0.00	clear
5/31	1	1	SE 16	S 8-16	8.9	15.5	5.0	9.5	0.00	clear
6/01	1	1	0	W 16	10.6	19.5	6.0	10.0	0.00	clear
6/02	4	2	0	SE 16-24	9.4	11.1	6.5	10.5	0.00	clear
6/03	1	1	0	NW 24	9.2	16.5	6.5	10.0	0.00	clear
6/04	1	1	NW 24	NW 32-48	12.8	15.5	7.0	10.0	0.00	clear
6/05	1	1	N 16	SE 24-32	10.6	12.0	6.0	10.5	0.00	clear
6/06	4	4	SW 16	SW 32	8.3	8.9	5.5	9.0	0.00	clear
6/07	4	4	W 08	W 8-11	6.7	6.1	6.5	6.5	0.10	clear
6/08	4	4	W 03	W 24	5.0	6.6	5.0	6.0	0.20	clear
6/09	3	3	W 08	W 24	6.1	10.0	4.0	6.0	0.02	clear
6/10	3	3	var. 3-24	NW 24-40	5.6	5.5	4.5	6.0	0.23	clear
6/11	3	2	NW 03	NW 24-32	3.9	10.0	3.5	7.0	0.05	clear
6/12	2	3	NW 16	NW 32	3.9	11.0	4.0	7.5	0.00	clear
6/13	3	-	0	-	6.1	-	4.0	-	0.25	-

[a] 1 = Cloud cover not more than 1/10
2 = Cloud cover not more than 1/2
3 = Cloud cover more than 1/2
4 = Completely overcast
5 = Fog

[b] var. = variable winds

[c] Water clarity at 0800 hours

Table 22. Water temperatures at sockeye salmon smolt counting site, Egegik River, 1981-1996.

		Water Temperature (°C)		
Year	Sample Period	Minimum	Mean	Maximum
1981	May 15 - June 08	7.0	8.2	10.0
1982	May 15 - June 16	2.5	4.9	8.5
1983	May 18 - June 10	5.2	7.9	10.5
1984	May 17 - June 11	5.5	7.9	10.0
1985	May 17 - June 12	2.0	4.6	7.0
1986	May 19 - June 12	1.0	4.6	7.0
1987	May 18 - June 13	4.5	6.7	9.0
1988	May 19 - June 14	3.0	7.1	11.0
1989	May 21 - June 10	3.0	5.8	8.8
1990	May 20 - June 11	3.5	7.3	9.5
1991	May 21 - June 12	1.0	4.8	8.5
1992	May 21 - June 12	5.0	7.8	10.0
1993	May 18 - June 09	4.0	6.6	11.0
1994	May 21 - June 10	1.5	6.1	11.0
1995	May 21 - June 13	2.0	7.0	12.5
	Mean	3.4	6.5	9.6
1996	May 19 - June 13	2.0	5.8	10.5

Table 23. Sonar counts recorded from two arrays at the sockeye salmon smolt counting site on Ugashik River, 1996.

Smolt Day [a]		Sonar Count: Transducer Array: Inshore	Sonar Count: Transducer Array: Offshore	Sonar Count: Total
5/19	[b]	883	4,024	4,907
5/20		838	1,537	2,375
5/21	[b]	569	647	1,216
5/22	[b c]	450	3,020	3,470
5/23	[b c]	2,565	6,541	9,106
5/24	[b c]	840	11,926	12,766
5/25		7,877	9,847	17,724
5/26		1,307	6,435	7,742
5/27		4,990	24,143	29,133
5/28	[c]	10,804	28,217	39,021
5/29		25,261	27,333	52,594
5/30		11,649	54,925	66,574
5/31		4,000	6,424	10,424
6/01		2,431	7,882	10,313
6/02		4,020	4,026	8,046
6/03		8,782	16,945	25,727
6/04	[c]	8,932	128,593	137,525
6/05		5,017	8,908	13,925
6/06		3,150	6,690	9,840
6/07		196	1,083	1,279
6/08		81	261	342
6/09		942	878	1,820
6/10	[b c]	861	3,730	4,591
6/11	[b]	560	3,425	3,985
Total		107,005	367,440	474,445
Percent		22.6	77.4	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

[b] Sonar counter disabled, but counts not able to be interpolated on the following hours and dates:

0400-1100 hours on May 20 due to snow and wind
1600-2100 hours on May 21 due to snow
1600-2200 hours on May 22 due to wind and waves
1600-2000 hours on May 23 due to wind and waves
1600-1900 hours on May 24 due to wind and waves
1500 hours on June 10 due to wind
0800-1500 hours on June 11 due to snow and wind

[c] Sonar counts interpolated for one or more arrays on the following hours and dates:

2300-2400 hours on May 22 due to breaking waves
0400-1100 hours on May 23 due to wind
1200-1500 hours on May 23 due to wind
2100 hours May 23 -1500 hours May 24 due to wind
1200-2400 hours May 28 due to wind
0100-1100 hours May 29 due to wind
1300-2100 hours June 04 due to wind
1600-1900 hours June 10 due to wind and rain

Table 24. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Ugashik River, 1996.

	Age 1.			Age 2.			All Ages	
Smolt Day [a]	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/19	8,398	37.5	8,398	13,972	62.5	13,972	22,370	22,370
5/20	4,945	37.5	13,343	8,227	62.5	22,199	13,172	35,542
5/21	2,819	37.5	16,162	4,690	62.5	26,889	7,509	43,051
5/22	5,576	37.5	21,738	9,278	62.5	36,167	14,854	57,905
5/23	17,521	37.5	39,259	29,153	62.5	65,320	46,674	104,579
5/24	14,066	30.0	53,325	32,805	70.0	98,125	46,871	151,450
5/25	41,176	39.3	94,501	63,651	60.7	161,776	104,827	256,277
5/26	15,950	42.0	110,451	21,981	58.0	183,757	37,931	294,208
5/27	56,064	38.8	166,515	88,580	61.2	272,337	144,644	438,852
5/28	55,278	27.1	221,793	149,003	72.9	421,340	204,281	643,133
5/29	114,072	32.8	335,865	233,286	67.2	654,626	347,358	990,491
5/30	114,148	34.3	450,013	218,549	65.7	873,175	332,697	1,323,188
5/31	24,028	37.2	474,041	40,477	62.8	913,652	64,505	1,387,693
6/01	13,672	25.9	487,713	39,036	74.1	952,688	52,708	1,440,401
6/02	26,527	46.5	514,240	30,496	53.5	983,184	57,023	1,497,424
6/03	64,601	41.2	578,841	92,274	58.8	1,075,458	156,875	1,654,299
6/04	383,604	57.0	962,445	288,913	43.0	1,364,371	672,517	2,326,816
6/05	60,099	61.8	1,022,544	37,070	38.2	1,401,441	97,169	2,423,985
6/06	60,471	81.9	1,083,015	13,391	18.1	1,414,832	73,862	2,497,847
6/07	6,584	81.9	1,089,599	1,458	18.1	1,416,290	8,042	2,505,889
6/08	1,927	81.9	1,091,526	426	18.1	1,416,716	2,353	2,508,242
6/09	13,081	81.9	1,104,607	2,896	18.1	1,419,612	15,977	2,524,219
6/10	23,875	81.9	1,128,482	5,287	18.1	1,424,899	29,162	2,553,381
6/11	18,705	79.8	1,147,187	4,726	20.2	1,429,625	23,431	2,576,812
	1,147,187	44.5		1,429,625	55.5		2,576,812	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 25. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Ugashik River, 1996.

Smolt Day [a]	Mean Weight of Smolt (g)	Smolt per Count
5/19	12.5	3.3
5/20	12.5	3.3
5/21	12.5	3.3
5/22	12.5	3.3
5/23	12.5	3.3
5/24	13.2	3.1
5/25	12.7	3.3
5/26	12.3	3.4
5/27	12.2	3.4
5/28	12.9	3.2
5/29	12.3	3.4
5/30	12.1	3.4
5/31	12.0	3.5
6/01	12.6	3.3
6/02	11.4	3.6
6/03	11.6	3.6
6/04	10.7	3.9
6/05	10.3	4.0
6/06	9.2	4.5
6/07	9.2	4.5
6/08	9.2	4.5
6/09	9.2	4.5
6/10	9.2	4.5
6/11	9.4	4.4

[a] Sample day began at 1200 hours and ended at 1159 hour the next calendar day.

Table 26. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by each age class, and number of smolt produced per spawner for 1979-1994 brood years, Ugashik River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced							
		Age 1.	(%[a])	Age 2.	(%[a])	Age 3.	(%[a])	Total	Per Spawner
79	1,700,904					0			
80	3,321,384			12,736,379		26,384			
81	1,326,762	31,297,432	27	82,656,993	73	0		113,954,425	85.89
82	1,157,526	75,491,249	78	21,407,762	22	0		96,899,011	83.71
83	1,000,614	12,693,628	46	15,186,101	54	1,677		27,881,406	27.86
84	1,241,418	37,890,152	64	21,483,727	36	9,598		59,383,477	47.84
85	998,232	5,461,821	14	33,238,739	86	0		38,700,560	38.77
86	1,001,493	182,719,678	85	32,278,743	15	0		214,998,421	214.68
87	668,964	94,019,379	71	38,789,387	29	0		132,808,766	198.53
88	642,972	14,837,960	24	47,713,086	76	-[b]		62,551,046[c]	97.28[c]
89	1,681,302	26,056,791		-[b]		0		26,056,791[c]	15.50[c]
90	730,038	-[b]		12,415,518		0		12,415,518[c]	17.01[c]
91	2,457,306	58,331,556	91	5,725,543	9	0		64,057,099	26.07
92	2,173,692	24,305,081	61	15,272,807	39	0		39,577,888	18.21
93	1,389,534	6,961,330	83	1,429,625[d]	17			8,390,955[c]	6.04[c]
94	1,080,858	1,147,187[d]						[c]	[c]
Max	3,321,384	182,719,678		82,656,993		26,384		214,998,421	214.68
Avg	1,410,812	43,939,480		26,179,570		2,897		78,109,369	76.81
Min	642,972	1,147,187		1,429,625		0		8,390,955	6.04

[a] Percent of total smolt production.

[b] No smolt data collected in 1992, therefore smolt production data for the 1988 (Age 3.), 1989 (Age 2.), and 1990 (Age 1.) brood years are incomplete.

[c] Incomplete returns from brood year escapements.

[d] Need adult returns through 1999 to validate this smolt estimate.

Table 27. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1979-1994 brood years, Ugashik River.

		Age 1.			Age 2.			Age 3.		
Brood Year	Total Spawning Escapement	Number of Smolt	Adult Returns [a]	Adult Returns per Smolt	Number of Smolt	Adult Returns [a]	Adult Returns per Smolt	Number of Smolt	Adult Returns [a]	Adult Returns per Smolt
1979	1,700,904		3,960,210			2,045,642			0	[b]
1980	3,321,384		3,503,629		12,736,379	4,262,289	0.33	26,384	2,600	0.10
1981	1,326,762	31,297,432	4,241,375	0.14	82,656,993	3,215,237	0.04	0	1,682	[b]
1982	1,157,526	75,491,249	1,146,491	0.02	21,407,762	1,345,244	0.06	0	0	
1983	1,000,614	12,693,628	995,579	0.08	15,186,101	957,859	0.06	1,677	957	[b]
1984	1,241,418	37,890,152	1,052,811	0.03	21,483,727	4,394,930	0.20	9,598	5,707	[b]
1985	998,232	5,461,821	1,233,687	0.23	33,238,739	1,465,357	0.04	0	0	
1986	1,001,493	182,719,678	3,055,686	0.02	32,278,743	3,681,875	0.11	0	4,478	[b]
1987	668,964	94,019,379	2,501,539	0.03	38,789,387	4,271,781	0.11	0	34,988	[b]
1988	642,972	14,837,960	1,204,275	0.08	47,713,086	4,475,380	0.09	[c]	29,260	[b]
1989	1,681,302	26,056,791	1,116,433	0.04	[c]	3,443,912	[b]	0	8,504 [d]	[b]
1990	730,038	[c]	1,044,389	[b]	12,415,518	3,535,155 [d]	0.28 [d]	0	1,713 [d]	
1991	2,457,306	58,331,556	5,183,124 [d]	0.09 [d]	5,725,543	600,559 [d]		0	0 [d]	
1992	2,173,692	24,305,081	193,790 [d]		15,272,807	3,937 [d]		0		
1993	1,389,534	6,961,330	1,935 [d]		1,429,625 [e]					
1994	1,080,858	1,147,187 [e]								
Max	3,321,384	182,719,678	4,241,375	0.23	82,656,993	4,475,380	0.33	26,384	34,988	0.10
Avg	1,410,812	43,939,480	2,182,883	0.07	26,179,570	3,050,864	0.12	3,138	7,967	0.05
Min	642,972	1,147,187	995,579	0.02	1,429,625	957,859	0.04	0	0	0.00

[a] Includes estimates of returns through 1996.

[b] Insufficient smolt data to complete this calculation.

[c] No Ugashik River smolt enumeration project conducted in 1992. Therefore smolt estimates for 1988, 1989, and 1990 brood years are incomplete because no smolt data were collected in 1992.

[d] Future adult returns will increase these values.

[e] Need adult returns through 1999 to validate this smolt estimate.

Table 28. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Ugashik River, 1996.

	Age 1.					Age 2.				
Smolt Day [a]	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/20	104	9.4	9.9	2.70	28	117	17.2	14.0	6.14	24
5/21	110	11.5	12.2	4.21	29	120	14.4	15.7	5.31	71
5/22	78	15.3	4.4	2.47	4	104		9.5		1
5/23	102	28.7	10.5	6.64	62	115	18.2	14.2	5.58	38
5/24	106	26.3	11.7	6.34	43	115	13.0	14.5	4.96	57
5/25	110	17.3	12.3	5.34	42	118	14.3	15.2	5.43	57
5/26	106	15.0	12.0	4.57	34	116	13.8	15.2	5.70	66
5/27	103	25.1	10.8	6.03	32	116	19.4	13.9	4.58	68
5/28	106	16.1	11.5	5.28	17	116	15.5	15.0	6.11	83
5/29	102	19.9	10.1	6.85	26	115	12.3	13.5	4.30	74
5/30	98	15.7	8.9	4.64	15	112	11.7	12.7	3.92	85
5/31	102	13.2	10.4	3.85	16	112	9.7	13.1	4.05	84
6/01	105	12.9	11.0	4.14	9	114	16.6	13.4	3.48	91
6/02	96	13.9	9.3	4.06	30	112	11.4	13.7	3.46	70
6/03	98	21.1	9.1	4.78	30	111	12.9	12.5	4.57	70
6/04	95	13.9	7.8	3.67	35	111	15.2	12.0	5.28	65
6/10	91	9.3	6.9	2.15	36	107	15.9	11.4	4.58	14
Total					488					1,018
Mean	101		9.9			114		13.5		

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 29. Age compostion of total migration and mean fork length and weight by age class for sockeye salmon smolt, Ugashik River, 1958-1996.

	Age 1.				Age 2.				Age 3.				
Year of Migration	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Brood Year	Percent of Total Estimate	Mean Length (mm)	Mean Weight (g)	Total Estimate [a]
1958	1956	-	93	6.4	1955	-	112	11.7	1954	-	-	-	-
1959	1957	-	90	6.1	1956	-	120	13.5	1955	-	-	-	-
1960	1958	-	90	6.6	1957	-	104	11.0	1956	-	-	-	-
1961	1959	-	90	6.7	1958	-	112	12.2	1957	-	-	-	-
1962	1960	-	88	6.1	1959	-	112	12.3	1958	-	-	-	-
1963	1961	-	90	6.1	1960	-	104	9.6	1959	-	-	-	-
1964	1962	-	92	6.9	1961	-	118	12.7	1960	-	-	-	-
1965	1963	-	94	6.9	1962	-	114	12.5	1961	-	-	-	-
1967	1965	-	88	6.0	1964	-	113	12.2	1963	-	-	-	-
1968	1966	-	93	6.5	1965	-	113	10.7	1964	-	-	-	-
1969	1967	-	97	7.5	1966	-	121	14.5	1965	-	-	-	-
1970	1968	-	97	7.7	1967	-	125	15.9	1966	-	-	-	-
1972	1970	-	81	5.0	1969	-	112	11.2	1968	-	129	14.3	-
1973	1971	-	93	7.2	1970	-	113	11.9	1969	-	132	20.1	-
1974	1972	-	94	7.4	1971	-	119	13.6	1970	-	-	-	-
1975	1973	-	96	7.2	1972	-	116	13.0	1971	-	125	16.7	-
1982	1980	-	88	6.3	1979	-	113	13.0	1978	-	138	22.5	-
1983	1981	71	89	7.6	1980	29	111	13.2	1979	-	-	-	44,033,811
1984	1982	48	87	6.8	1981	52	102	10.3	1980	0	103	11.7	158,174,626
1985	1983	37	94	8.3	1982	63	107	11.8	1981	-	-	-	34,101,390
1986	1984	71	87	5.8	1983	29	114	10.9	1982	-	-	-	53,076,253
1987	1985	20	94	7.9	1984	80	107	11.1	1983	0	138	24.1	26,947,225
1988	1986	85	87	5.7	1985	15	109	10.8	1984	0	128	15.6	215,968,015
1989	1987	74	90	6.5	1986	26	108	10.7	1985	-	-	-	126,298,122
1990	1988	28	90	6.7	1987	72	108	11.8	1986	-	-	-	53,627,347
1991	1989	35	92	7.7	1988	65	107	11.6	1987	-	-	-	73,769,877
1992 [b]	1990	-	-	-	1989	-	-	-	1988	-	-	-	-
1993	1991	83	92	8.0	1990	17	109	12.5	1989	-	-	-	70,747,074
1994	1992	81	89	6.7	1991	19	109	11.2	1990	-	-	-	30,030,624
1995	1993	31	93	7.8	1992	69	106	11.1	1991	-	-	-	22,234,137
Mean			88	6.6			108	11.6			128	17.9	
1996	1994	44	101	9.9	1993	56	114	13.5	1992		-	-	2,576,812
% Difference			15	50			6	16					

[a] No estimates of smolt numbers from 1958-1982 fyke net catches; estimates of smolt numbers from 1983-1991 and 1993-1996 based on hydroacoustic techniques.

[b] Project not operated in 1992. No smolt data collected.

Table 30. Mean fork length and estimated mean weight of age-1. and -2. sockeye salmon smolt, Ugashik River, 1996.

	Estimated Age 1. [a]				Estimated Age 2. [a]			
Smolt Day [b]	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Mean Weight (g)	Sample Size
5/21	101	11.5	9.8	20	116	13.1	14.3	65
5/23	102	21.1	10.2	93	117	22.3	14.6	310
5/24	101	25.0	10.0	112	117	22.8	14.5	402
5/25	98	34.7	9.1	179	117	24.1	14.5	333
5/26	101	27.6	9.9	201	114	17.0	13.5	300
5/27	98	31.4	9.3	194	114	24.2	13.8	342
5/28	102	19.4	10.1	84	115	18.6	13.9	349
5/29	95	33.7	8.5	153	115	20.6	13.9	365
5/30	100	27.3	9.7	169	113	17.6	13.4	354
5/31	101	25.7	9.8	190	112	12.1	13.1	319
6/01	102	17.8	10.2	115	113	15.6	13.4	400
6/02	97	34.9	8.9	252	112	12.4	13.1	275
6/03	97	31.3	8.9	213	113	13.1	13.3	319
6/04	96	29.4	8.8	331	112	11.9	13.2	212
6/05	93	32.4	8.0	319	113	11.8	13.2	186
6/06	96	19.8	8.6	121	111	7.7	12.9	57
6/10	94	20.9	8.2	340	113	8.6	13.3	24
6/11	94	21.8	8.1	401	114	10.7	13.6	76
Total				3,487				4,688
Mean	98		9.2		114		13.6	

[a] Length-weight parameters by age group and discriminating length used to separate ages were:

Age 1. $a = -10.3585$ $b = 2.7363$ $r^2 = 0.89$ $n = 471$
Age 2. $a = -8.7542$ $b = 2.3972$ $r^2 = 0.66$ $n = 1,006$

Discriminating Length = 108.22 mm

[b] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 31. Depth of sockeye salmon smolt passage at Ugashik River sonar site, May 24 to June 10, 1996.

	Depth of Passage (cm)					
	Inshore Array [a] Smolt Schools		Offshore Array [b] Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom
Minimum	15	80	0	20	8	50
Mean	15	80	1	44	8	62
Maximum	15	80	3	55	9	68
n	1	1	10	10	11	11

[a] Average depth of inshore array on smolt day 6/04 was 268 cm.
[b] Average depth of offshore array on smolt day 6/04 was 294 cm.

Table 32. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Ugashik River, 1996.

Date	Cloud Cover [a]		Wind [b] Direction & Velocity (km/h)		Air Temperature (°C)		Water Temperature (°C)		Percipitation (mm)	Water Clarity [c]
	0800	2000	0800	2000	0800	2000	0800	2000		
5/19	3	1	W 08	W 18	-	-	4.0	4.0	0.00	clear
5/20	4	2	S 08	W 23	1.0	6.0	3.0	4.0	trace	clear
5/21	2	5	SW 05	S 08	2.0	0.0	3.0	3.0	snow?	clear
5/22	3	4	S 08	SE 32	2.0	6.0	3.0	4.0	0.00	clear
5/23	3	4	SE 32	SE 48	6.0	5.0	5.0	5.0	0.60	lt brown
5/24	4	4	SE 32-40	SE 26	5.0	6.0	5.0	6.0	0.02	lt brown
5/25	4	3	0	S 08	4.0	8.0	5.0	6.0	0.03	clear
5/26	4	4	0	E 13	7.0	7.0	7.0	6.0	0.05	clear
5/27	4	4	0	SE 08	6.0	9.0	6.0	6.0	trace	clear
5/28	4	3	SE 16-24	SE 40	7.0	6.0	7.0	7.0	0.00	clear
5/29	3	3	SE 32-40 +	SE 16	6.0	8.0	6.0	7.0	0.00	lt brown
5/30	1	2	0	W 10	8.0	11.0	6.0	7.0	0.00	clear
5/31	1	1	0	W 11	8.0	15.0	6.0	7.0	0.00	clear
6/01	4	1	SW 08	SW 24	6.0	18.0	5.0	6.0	0.00	clear
6/02	4	1	SW 08	SW 05	6.0	16.0	6.0	6.5	0.00	clear
6/03	2	1	W 05	W 13	9.0	19.0	5.0	6.5	0.00	clear
6/04	1	1	0	N 32	9.0	15.0	7.0	7.0	0.00	clear
6/05	2	1	SW 13	SE 16-24 +	7.0	15.0	7.0	7.5	0.00	clear
6/06	5	4	SW 16	SW 24	7.0	7.0	7.0	6.5	0.00	clear
6/07	4	4	SW 10	SW 10	6.0	6.0	6.0	5.0	0.15	clear
6/08	5	4	W 14	W 08	5.0	6.0	5.0	5.0	0.20	clear
6/09	4	4	W 24	W 13	6.0	6.0	5.0	6.0	trace	clear
6/10	3	3	W 10	W 15	5.0	6.0	5.0	5.5	0.05	clear
6/11	4	2	W 18	W 18	4.0	8.0	5.0	5.5	0.15	clear
6/12	2	-	W 16	-	7.0	-	5.0	-	0.05	-

[a] 1 = Cloud cover not more than 1/10
2 = Cloud cover not more than 1/2
3 = Cloud cover more than 1/2
4 = Completely overcast
5 = Fog

[b] var. = variable winds

[c] Water clarity at 0800 hours

Table 33. Water temperatures at sockeye salmon smolt counting site, Ugashik River, 1983-1996.

		Water Temperature (°C)		
Year	Sample Period	Minimum	Mean	Maximum
1983	May 23 - June 11	6.0	7.3	8.5
1984	May 20 - June 17	4.8	6.3	8.5
1985	May 17 - June 09	-1.0	4.3	7.0
1986	May 23 - June 28	2.0	5.6	7.0
1987	May 17 - June 13	4.0	5.9	9.0
1988	May 17 - June 13	3.5	6.6	10.0
1989	May 21 - June 16	3.0	5.8	8.8
1990	May 21 - June 14	3.0	5.9	8.0
1991	May 20 - June 14	4.0	5.9	8.5
1992				
1993	May 18 - June 11	5.0	6.5	9.0
1994	May 20 - June 13	4.5	6.5	10.0
1995	May 23 - June 12	4.0	6.2	9.0
	Mean	3.6	6.1	8.6
1996	May 19 - June 13	3.0	5.6	7.5

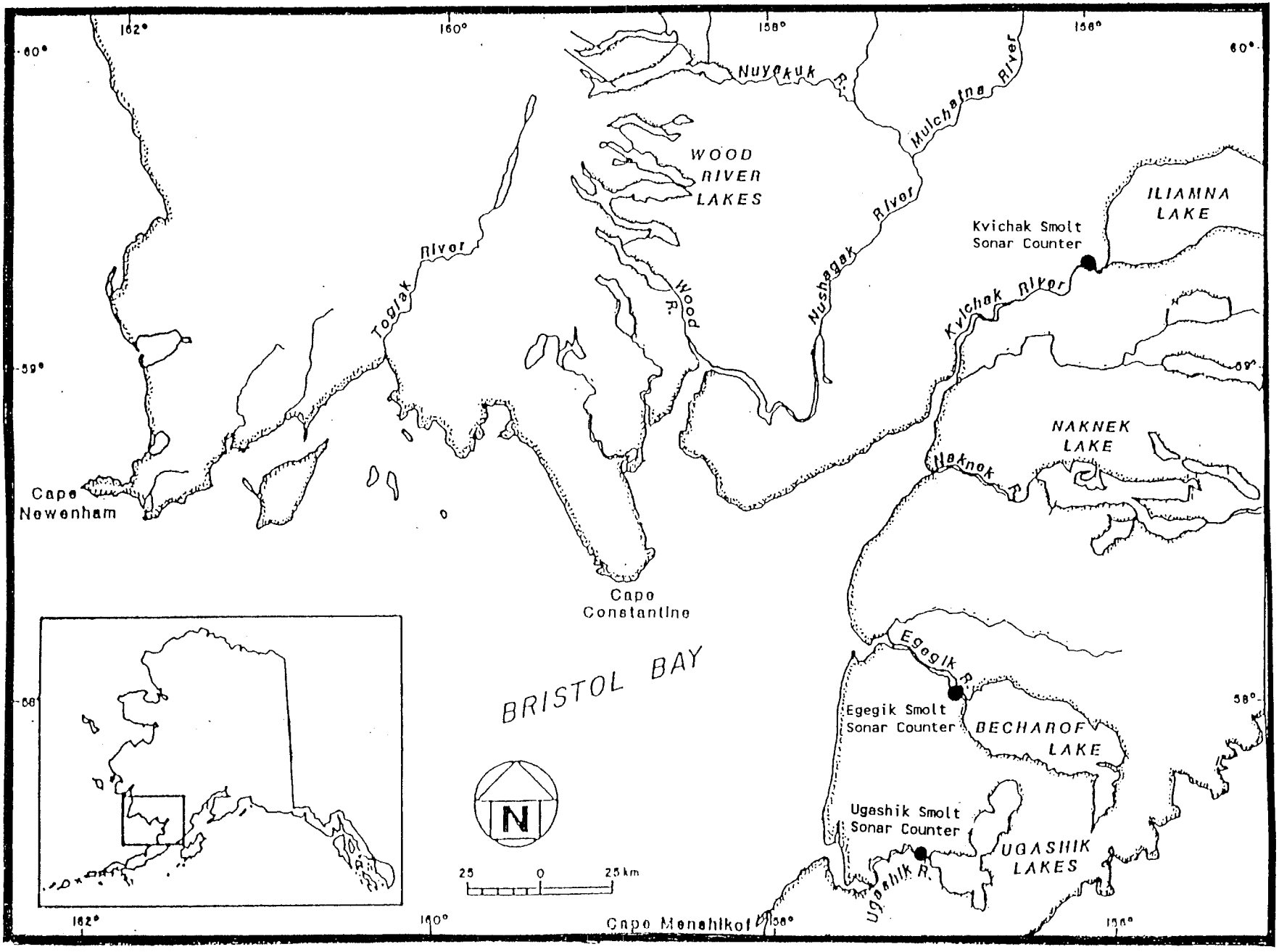


Figure 1. Bristol Bay Management Area with major rivers and locations of smolt counting projects, 1996.

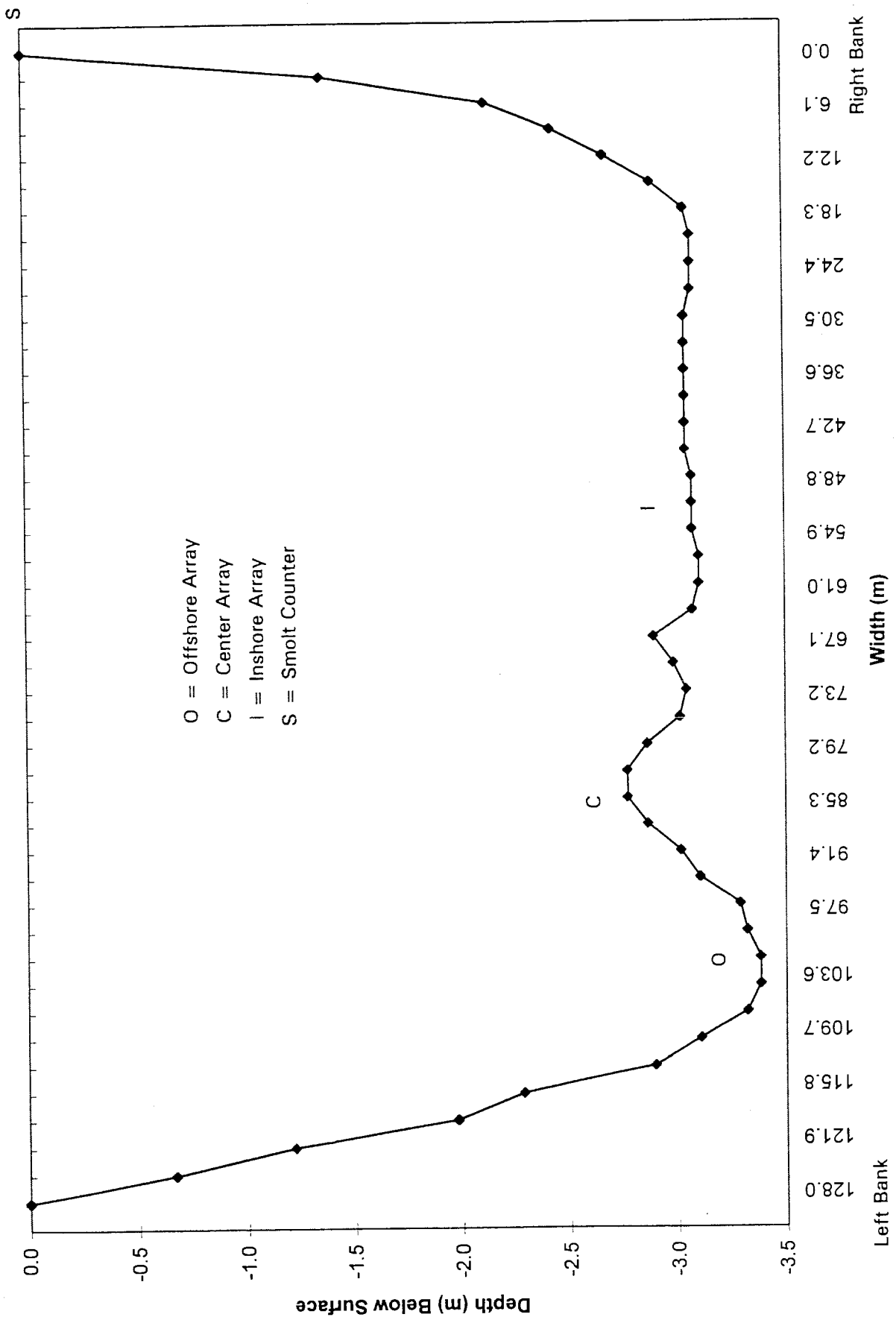


Figure 2. River bottom profile and sonar array placement at Kvichak River smolt site, 1996.

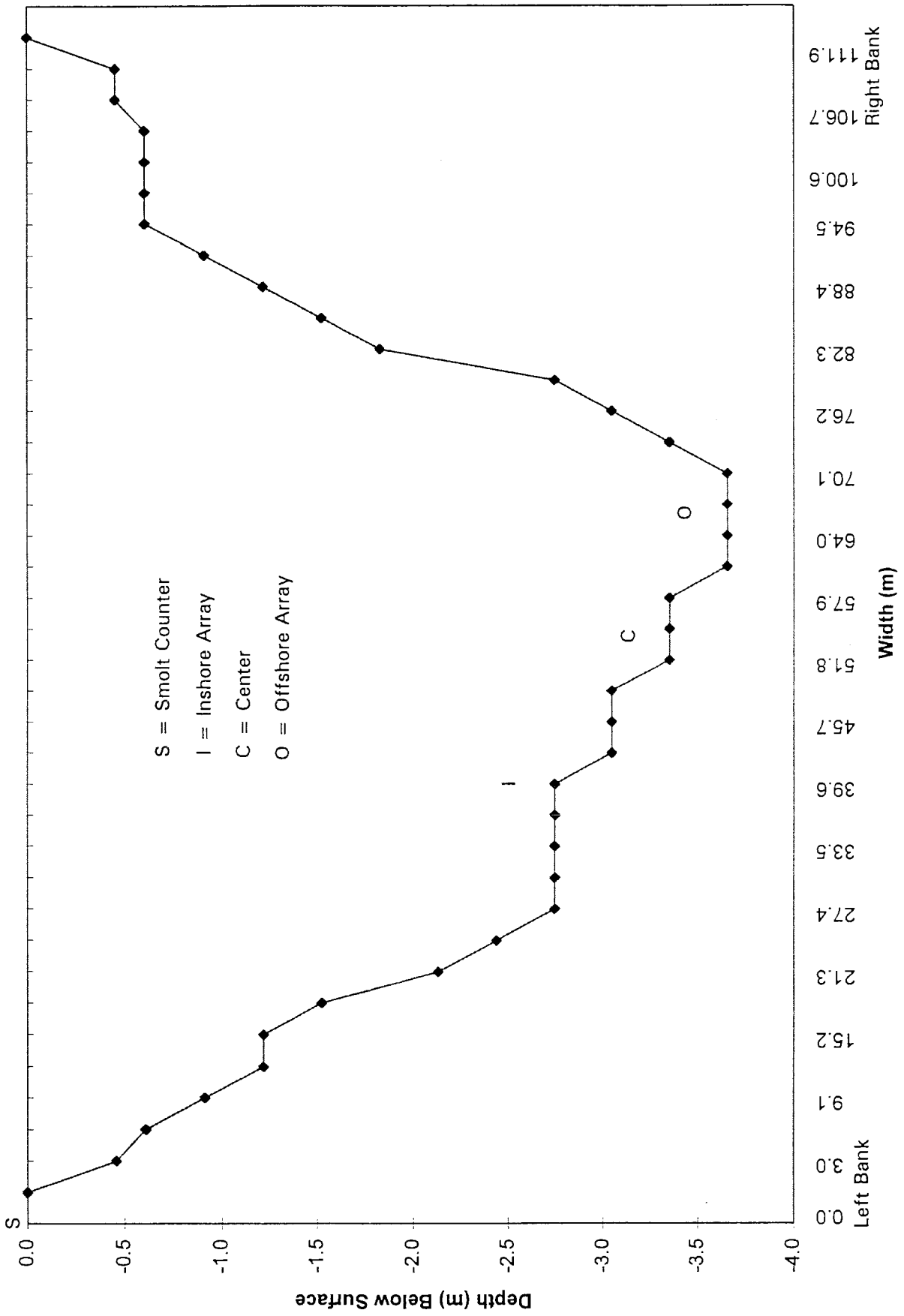


Figure 3. River bottom profile and sonar array placement at Egegik River smolt site, 1996.

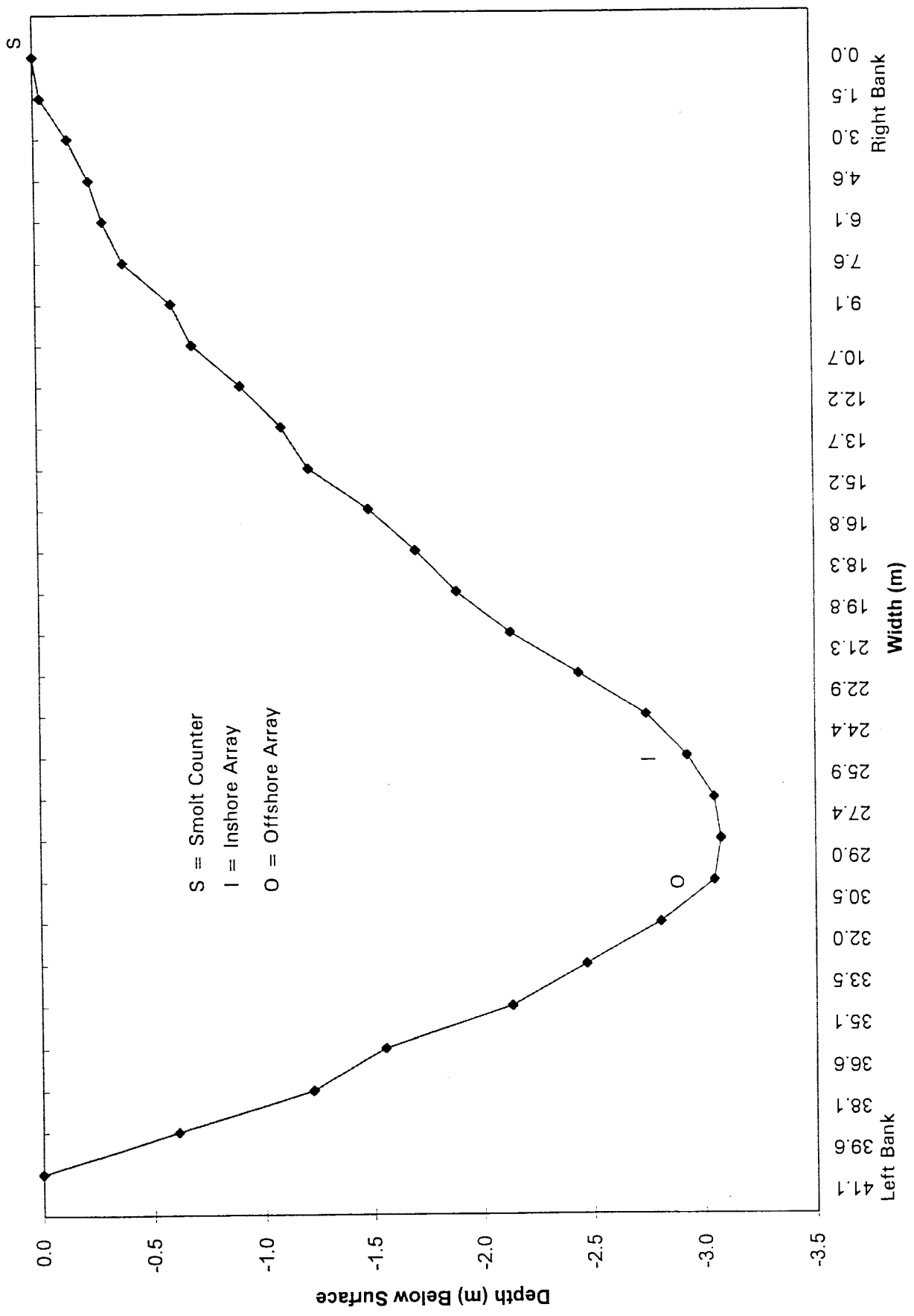


Figure 4. River bottom profile and sonar array placement at Ugashik River smolt site, 1996.

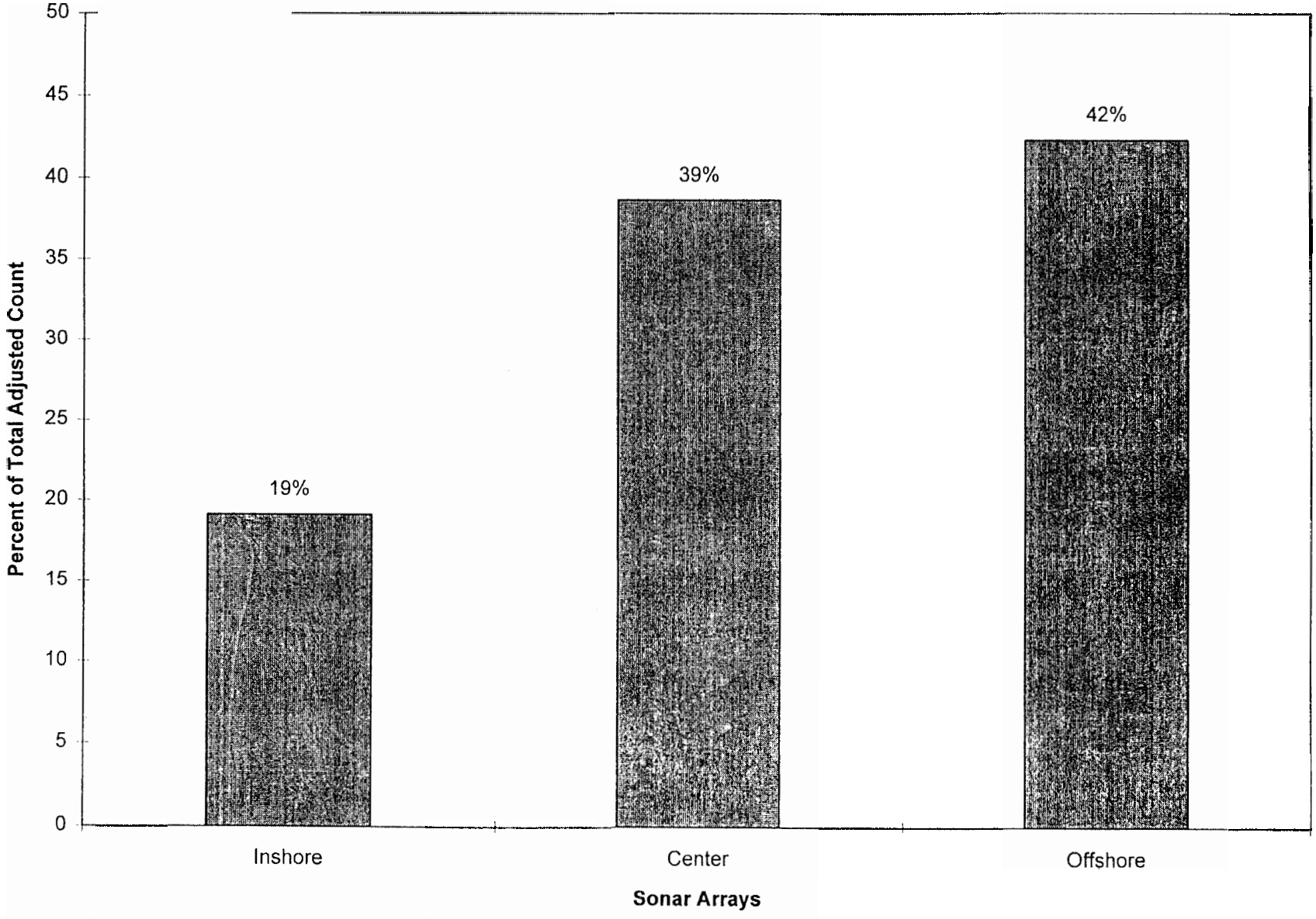


Figure 5. Lateral distribution of Kvichak River smolt sonar counts, 1996.

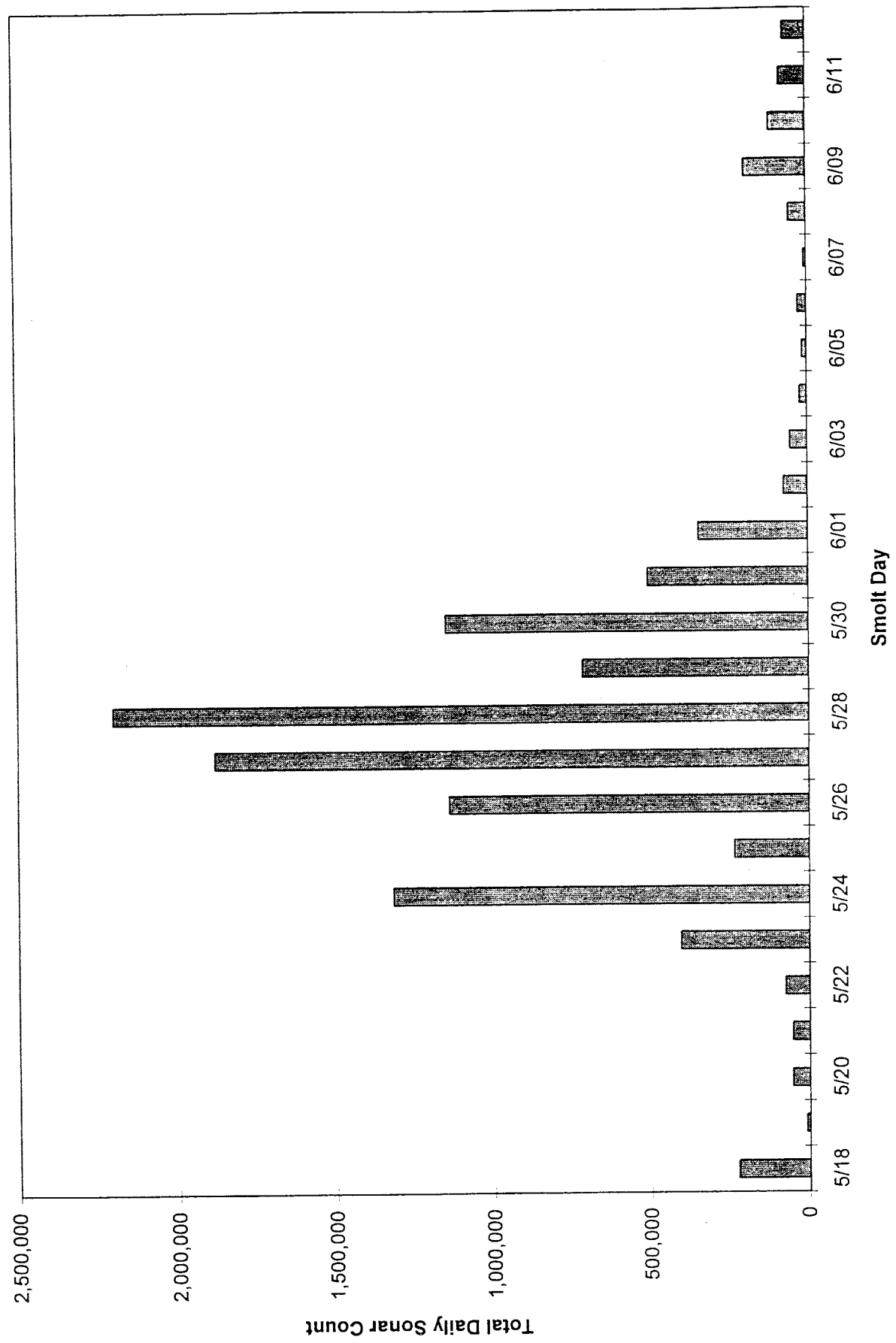


Figure 6. Total daily sonar counts at Kvichak River smolt project, May 18 to June 12, 1996.

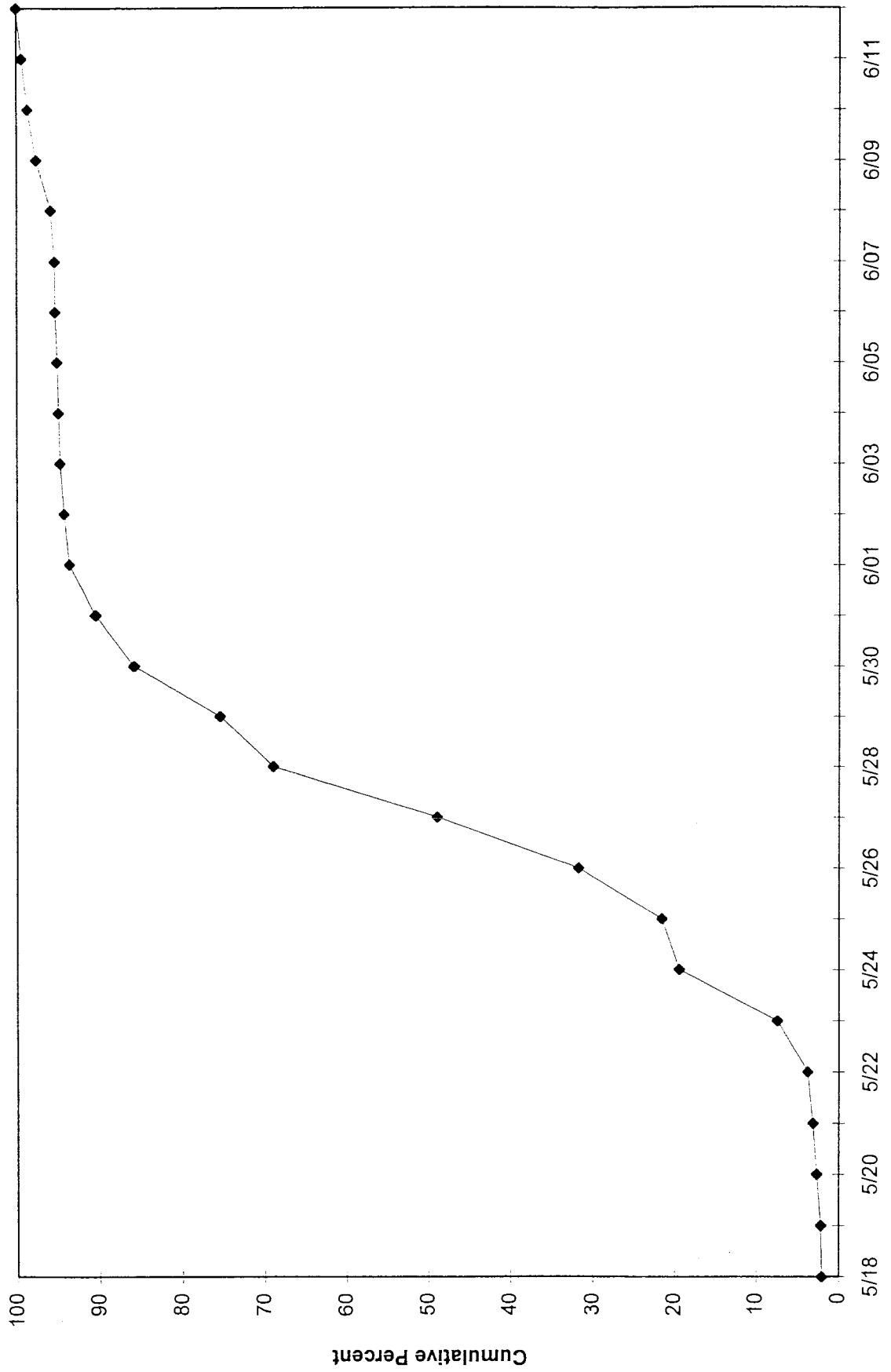


Figure 7. Kvichak River smolt sonar count, cumulative percent by smolt day, May 18 to June 12, 1996.

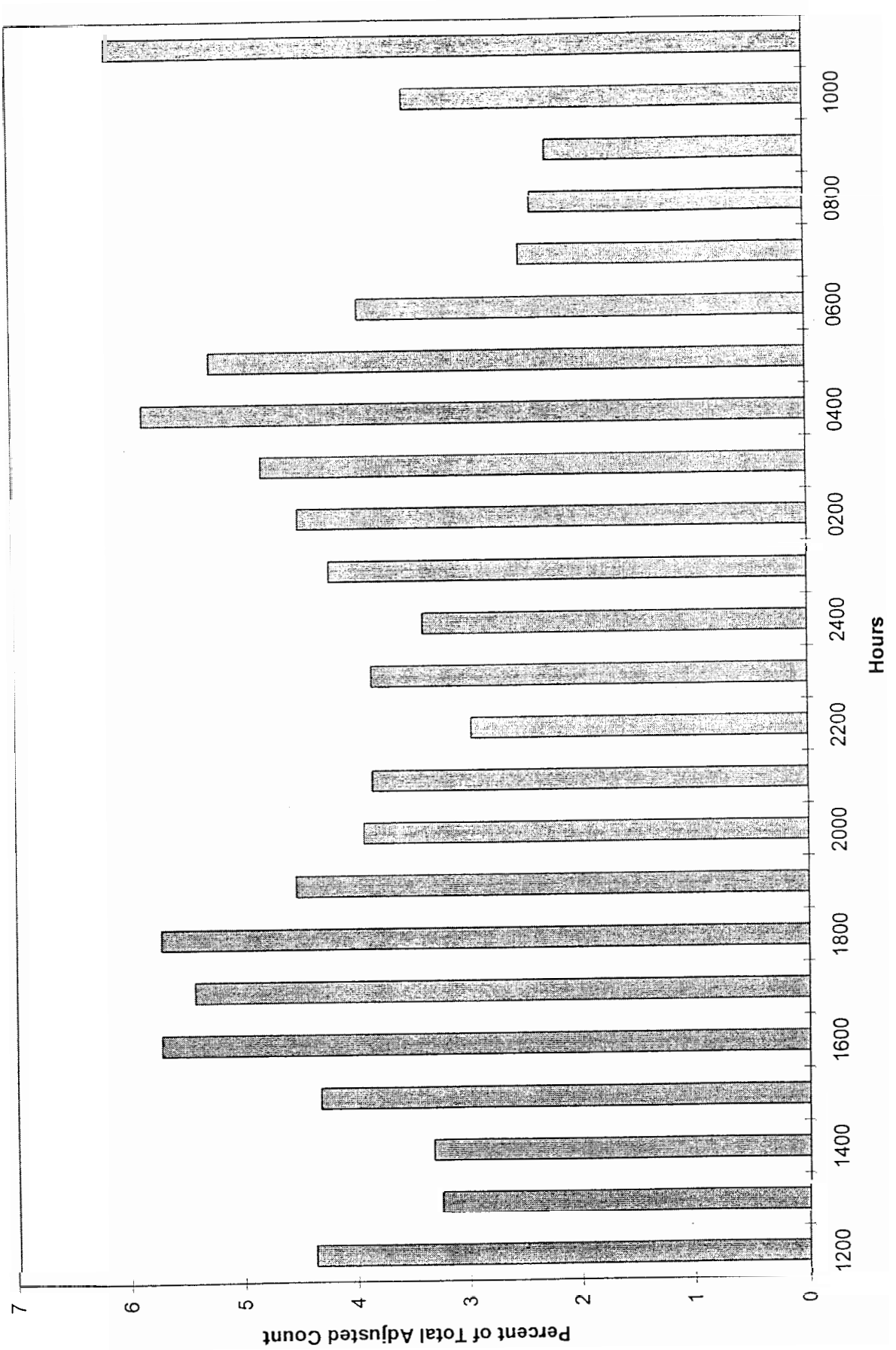
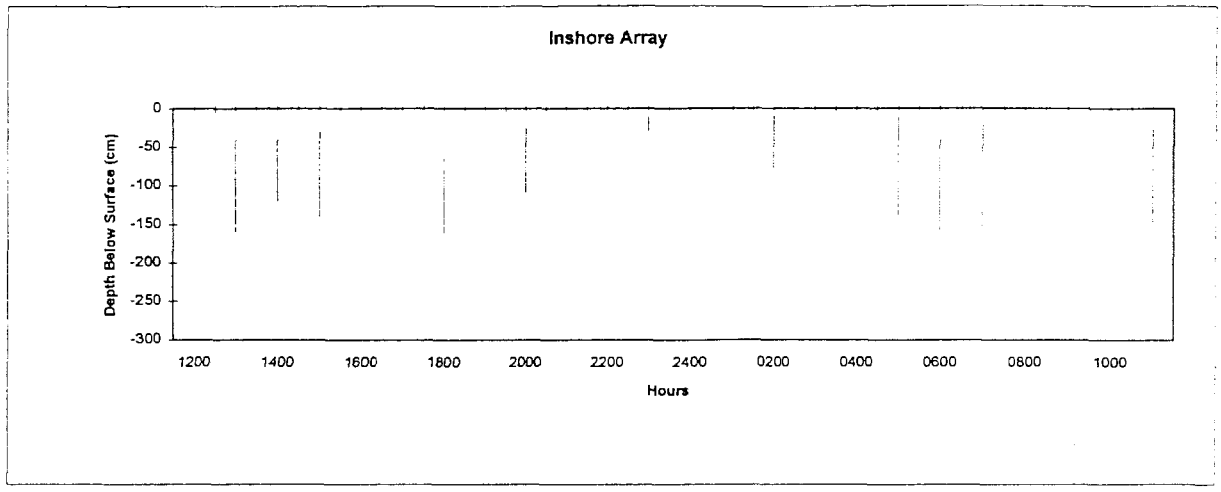
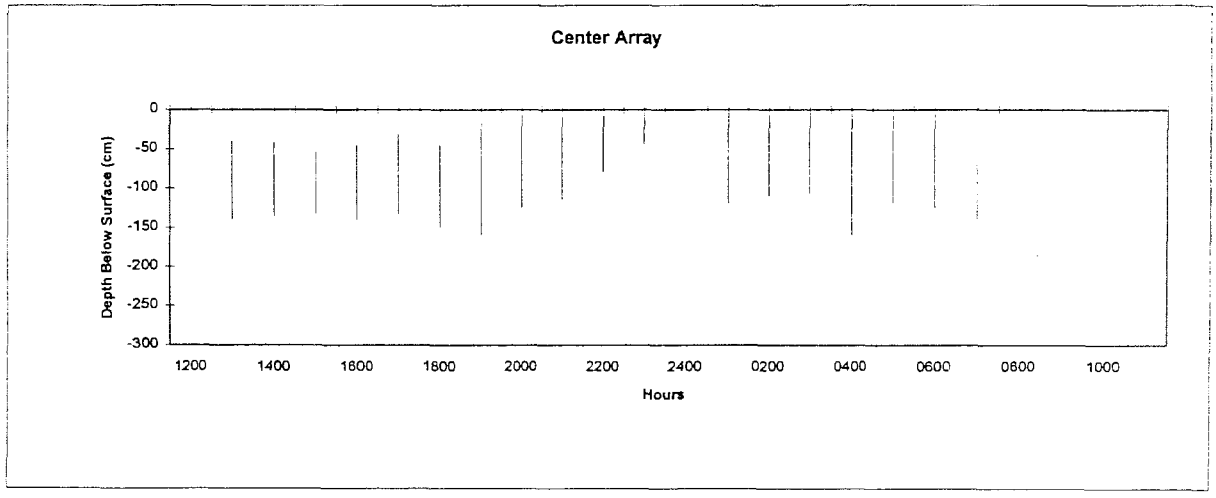


Figure 8. Percent of the total adjusted sonar count summarized by hour, Kvichak River smolt project, May 18 to June 12, 1996.





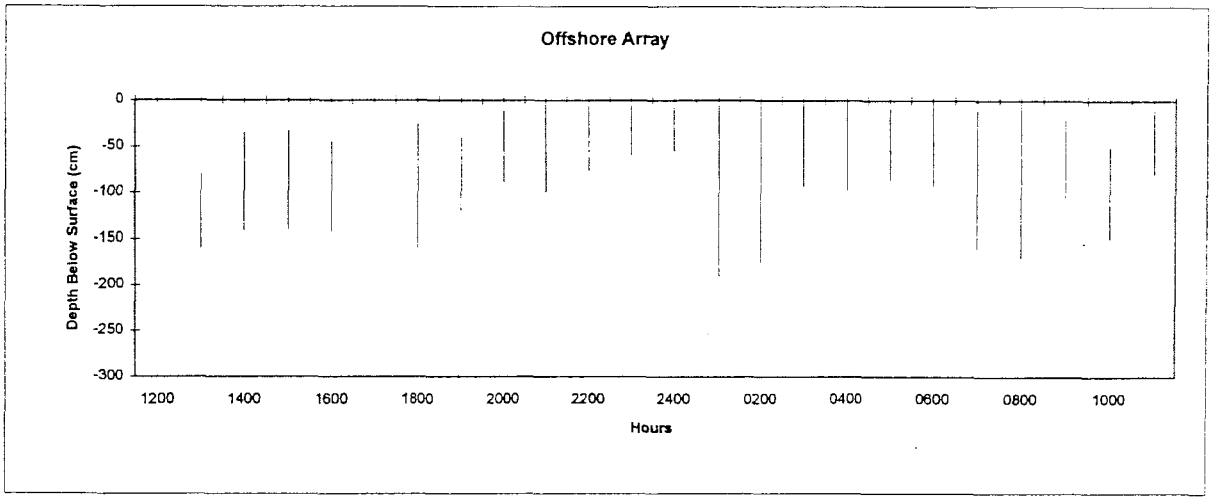


Figure 9. Depth of smolt passage data summarized by hour, Kvichak River, May 18 to June 11, 1996.

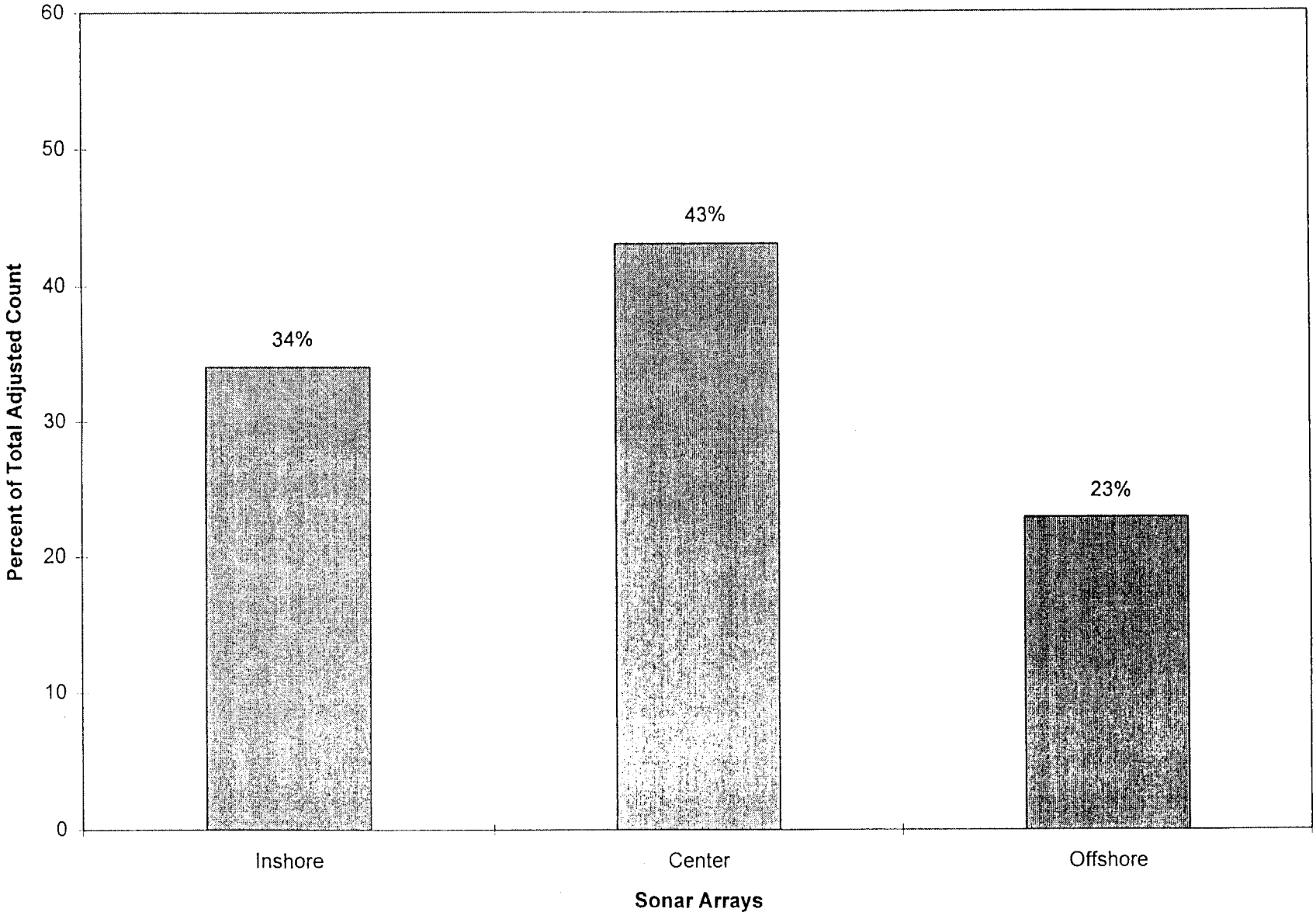


Figure 10. Lateral distribution of Egegik River smolt sonar counts, 1996.

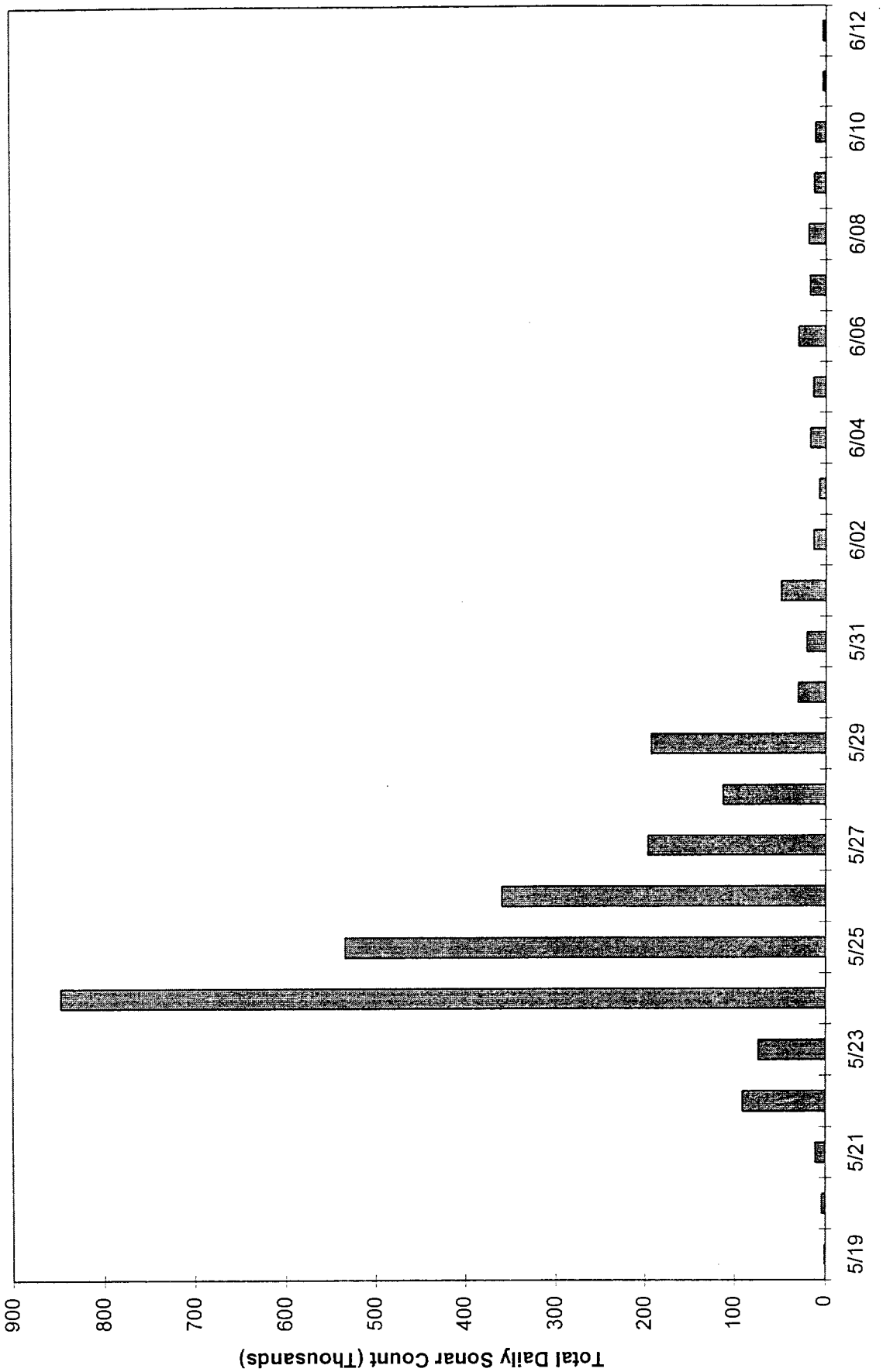


Figure 11. Total daily sonar counts at Egegik River smolt project, May 19 to June 12, 1996.

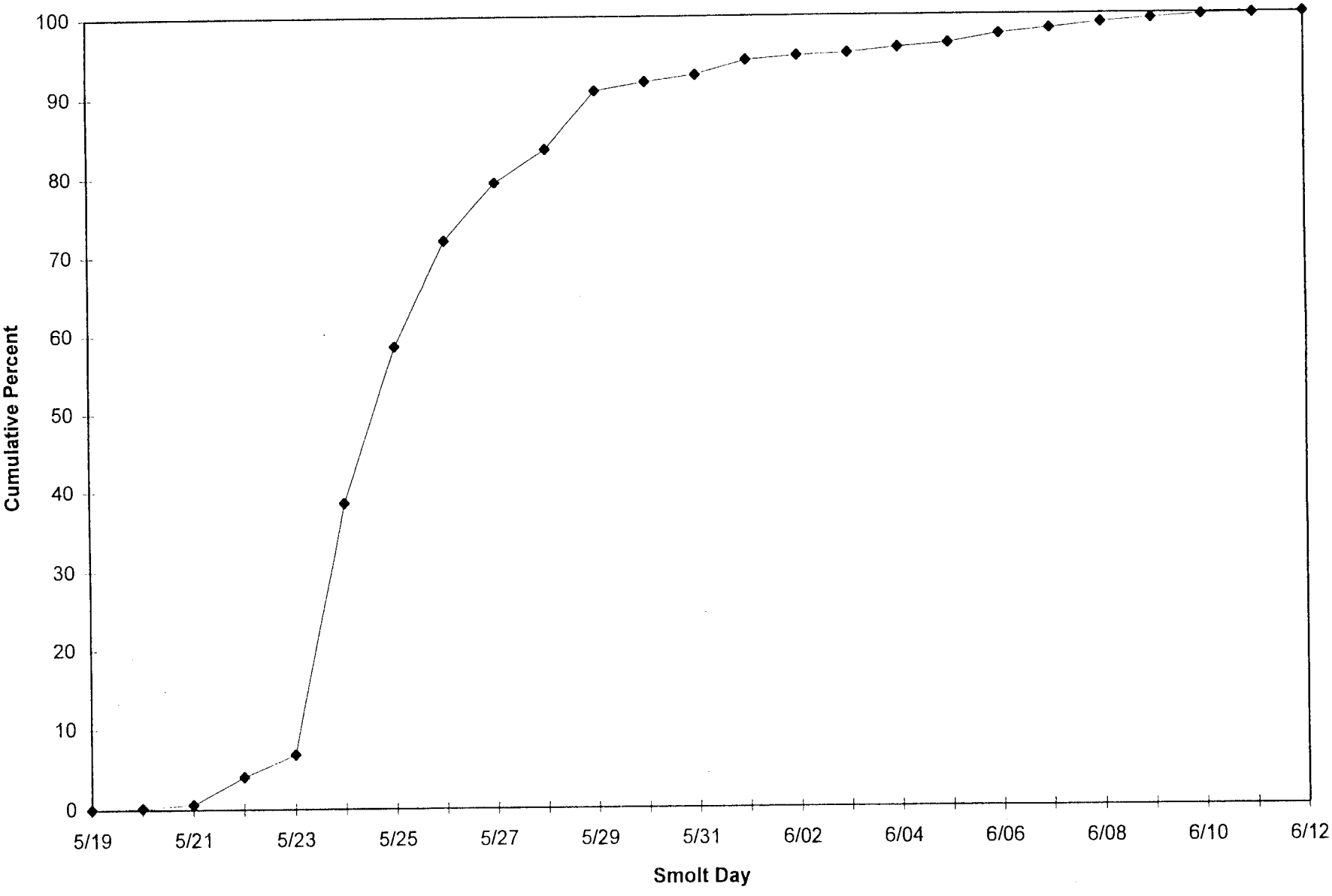


Figure 12. Egegik River smolt sonar count, cumulative percent by smolt day, May 19 to June 12, 1996.

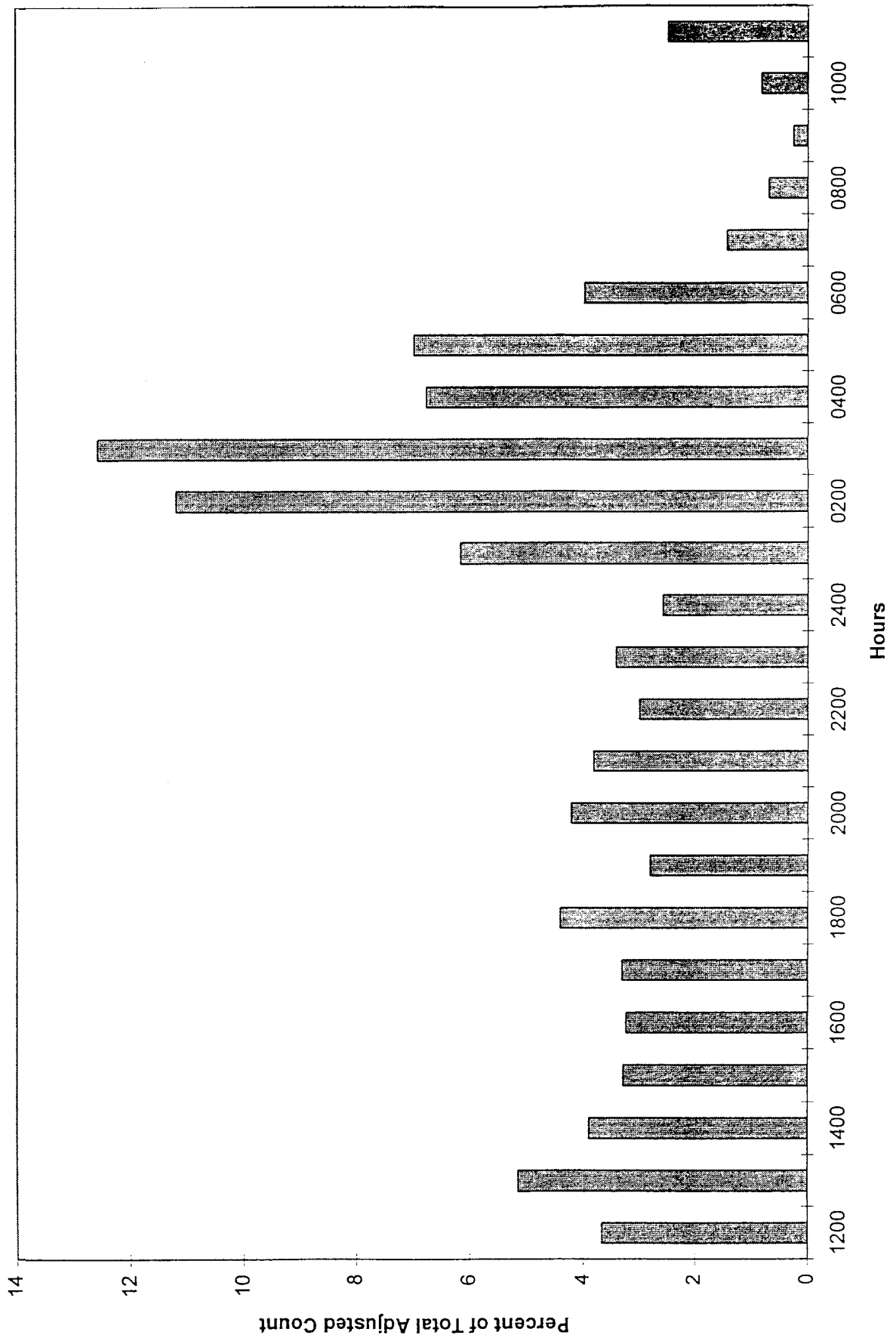
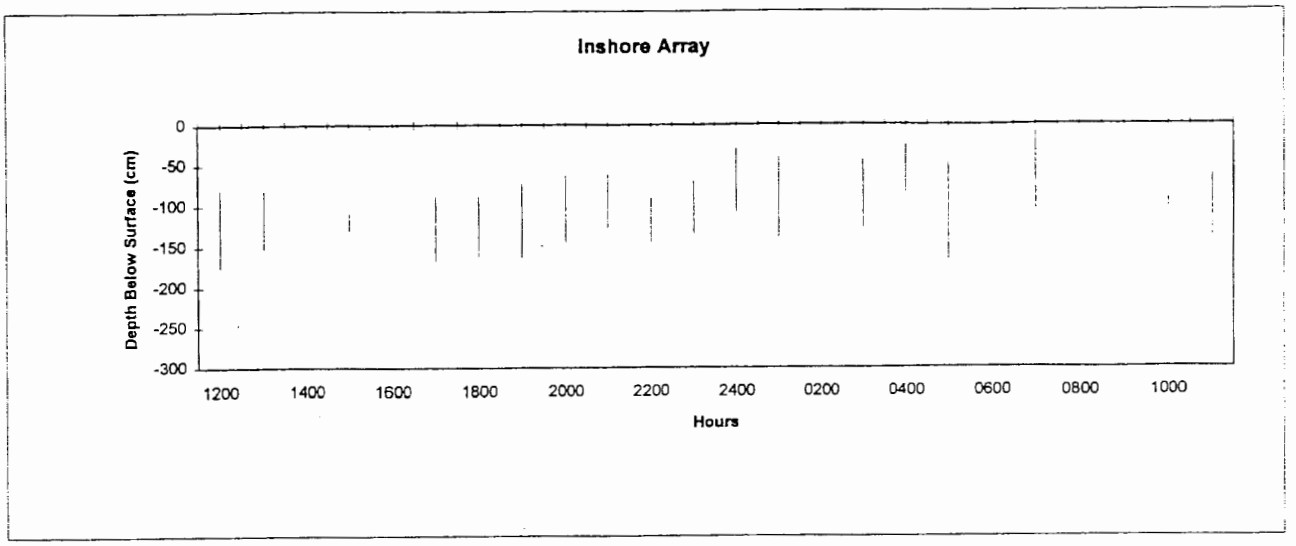
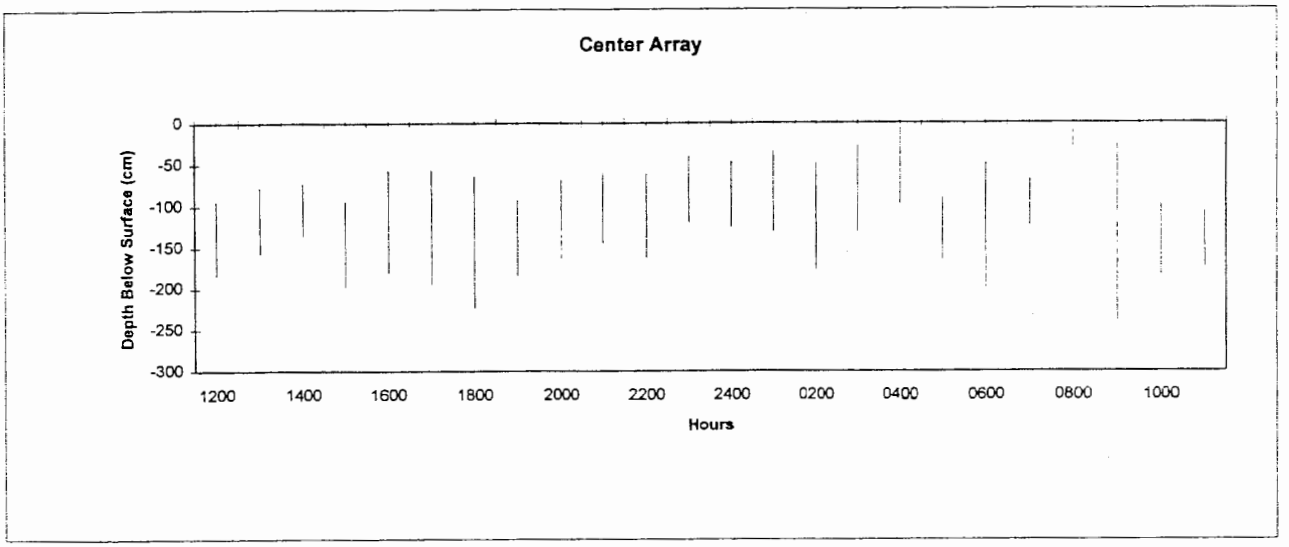


Figure 13. Percent of the total adjusted sonar count summarized by hour, Egegik River smolt project, May 19 to June 12, 1996.





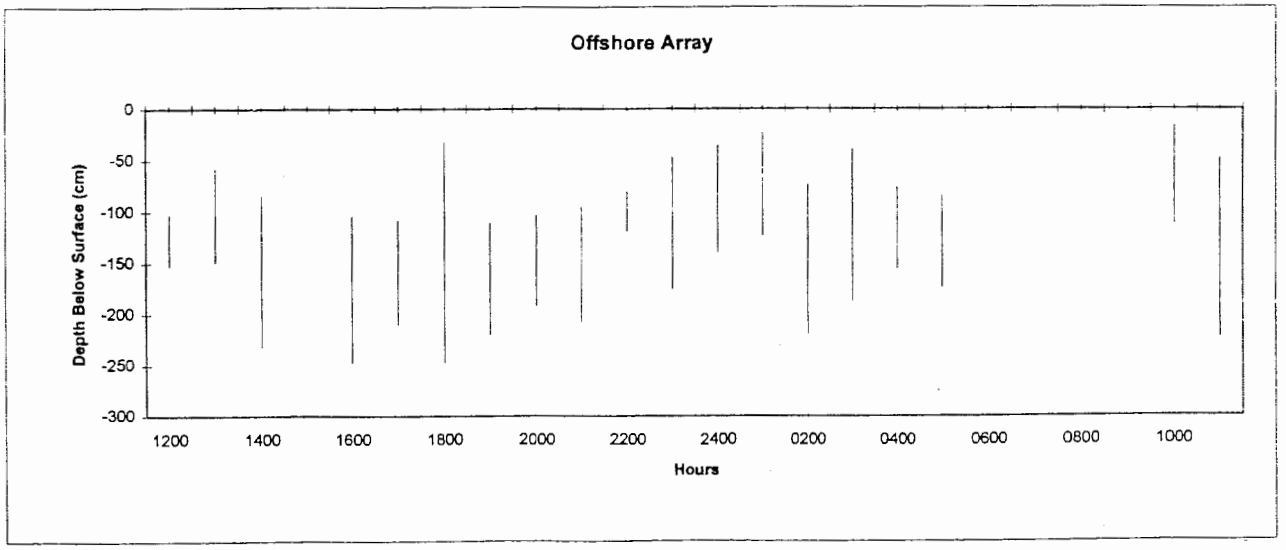


Figure 14. Depth of smolt passage data summarized by hour, Egegik River, May 21 to June 10, 1996.

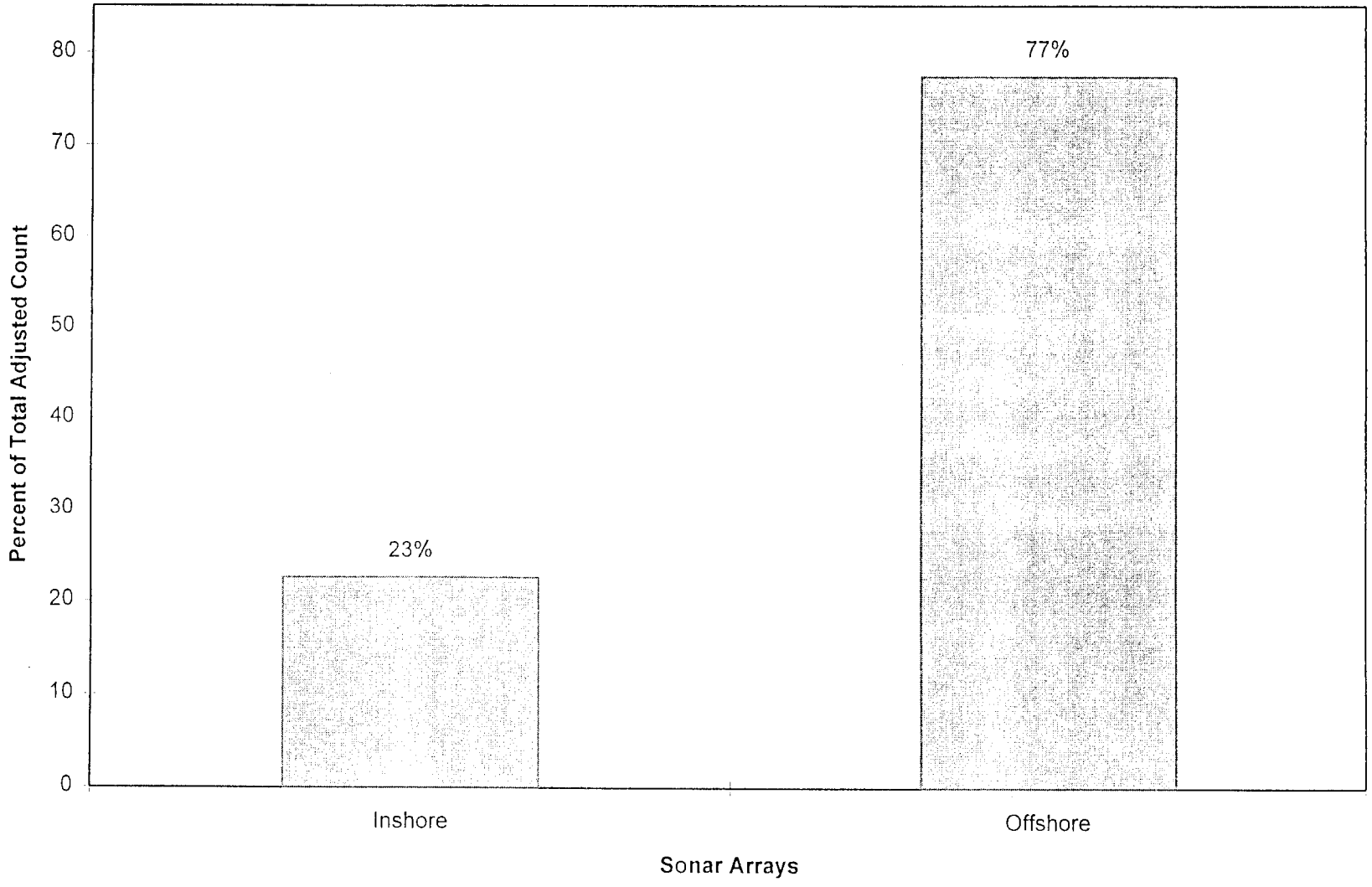


Figure 15. Lateral distribution of Ugashik River smolt sonar counts, 1996.

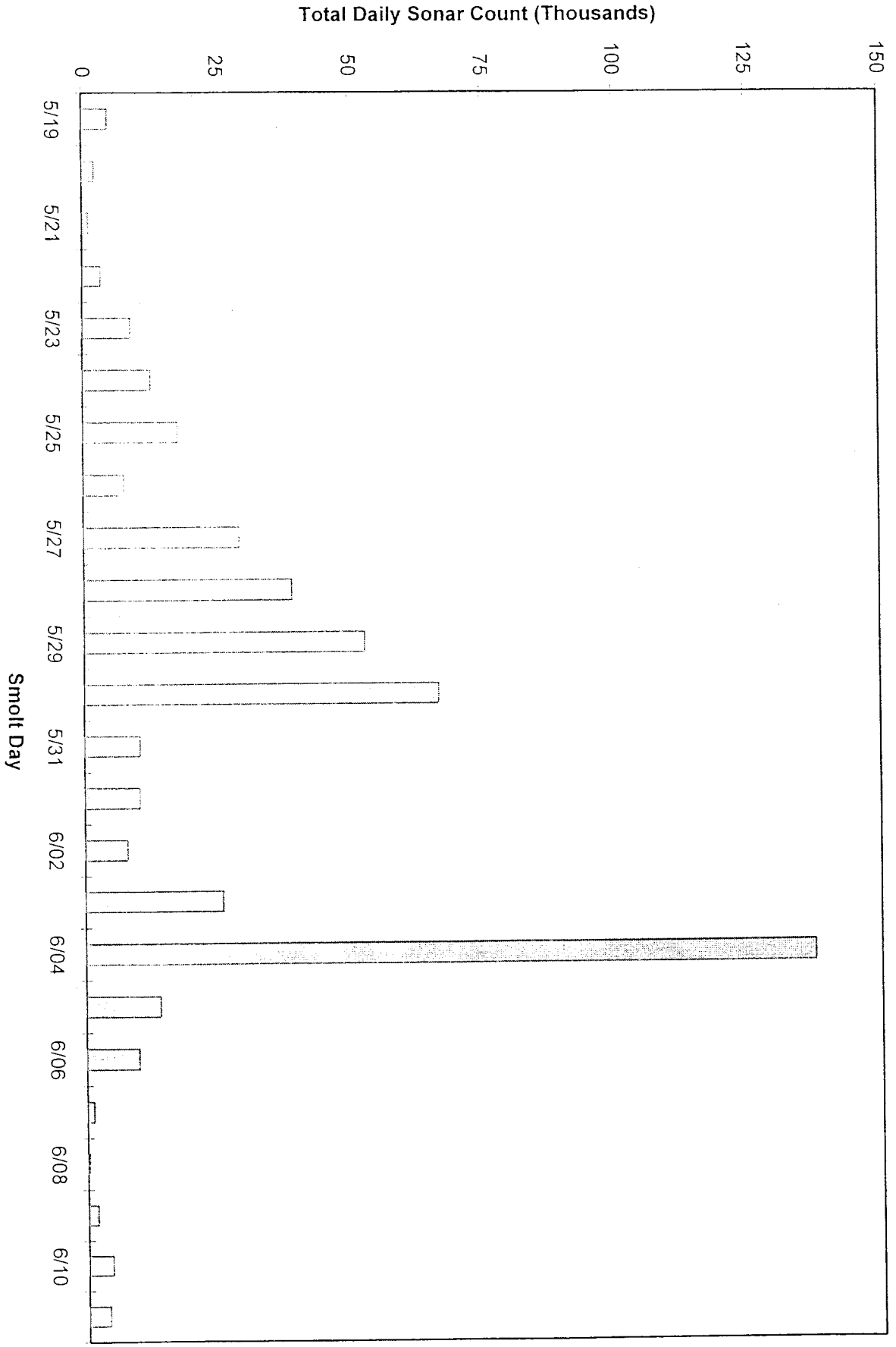


Figure 16. Total daily sonar counts at Ugashik River smolt project, May 19 to June 11, 1996.

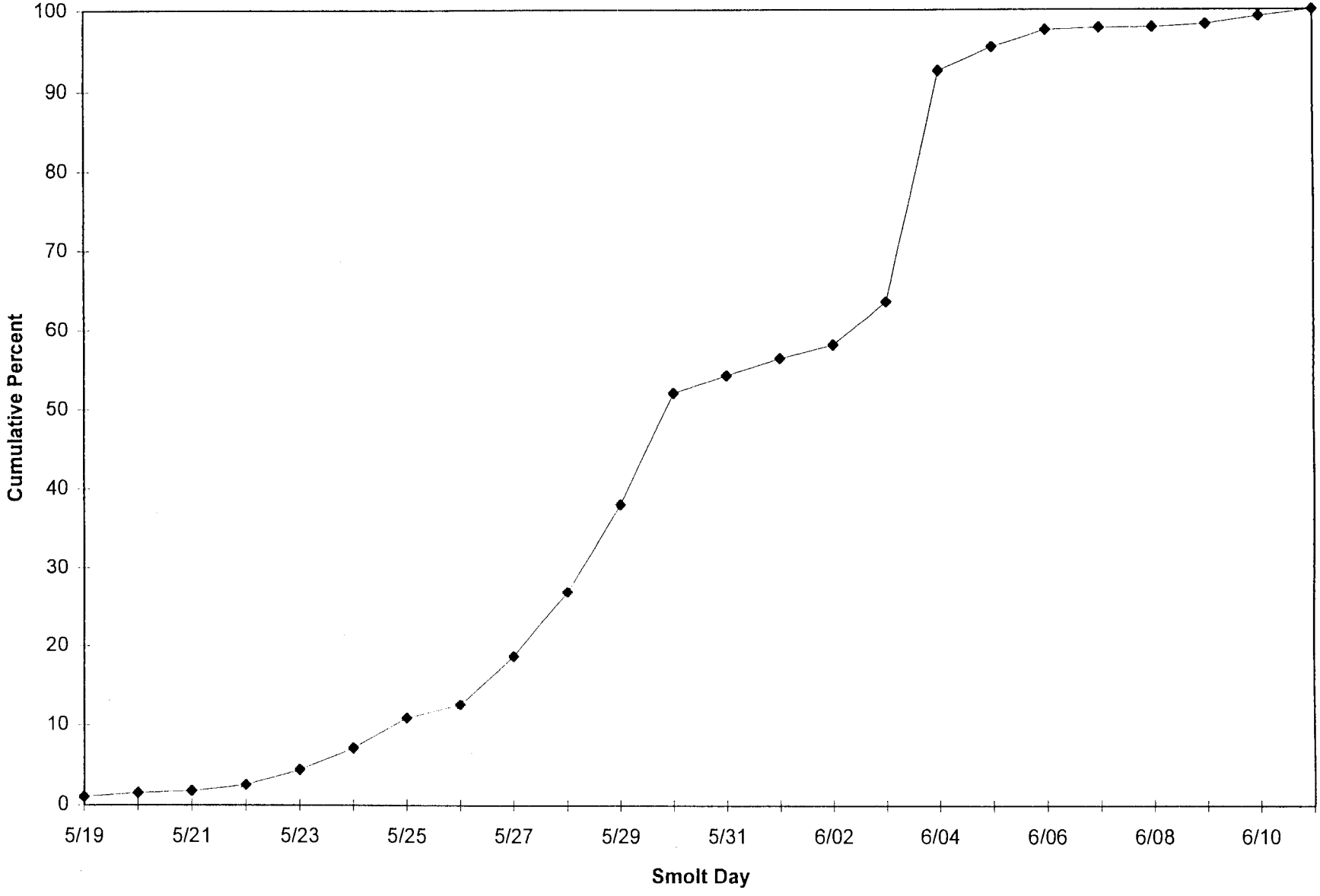


Figure 17. Ugashik River smolt sonar count, cumulative percent by smolt day, May 19 to June 11, 1996.

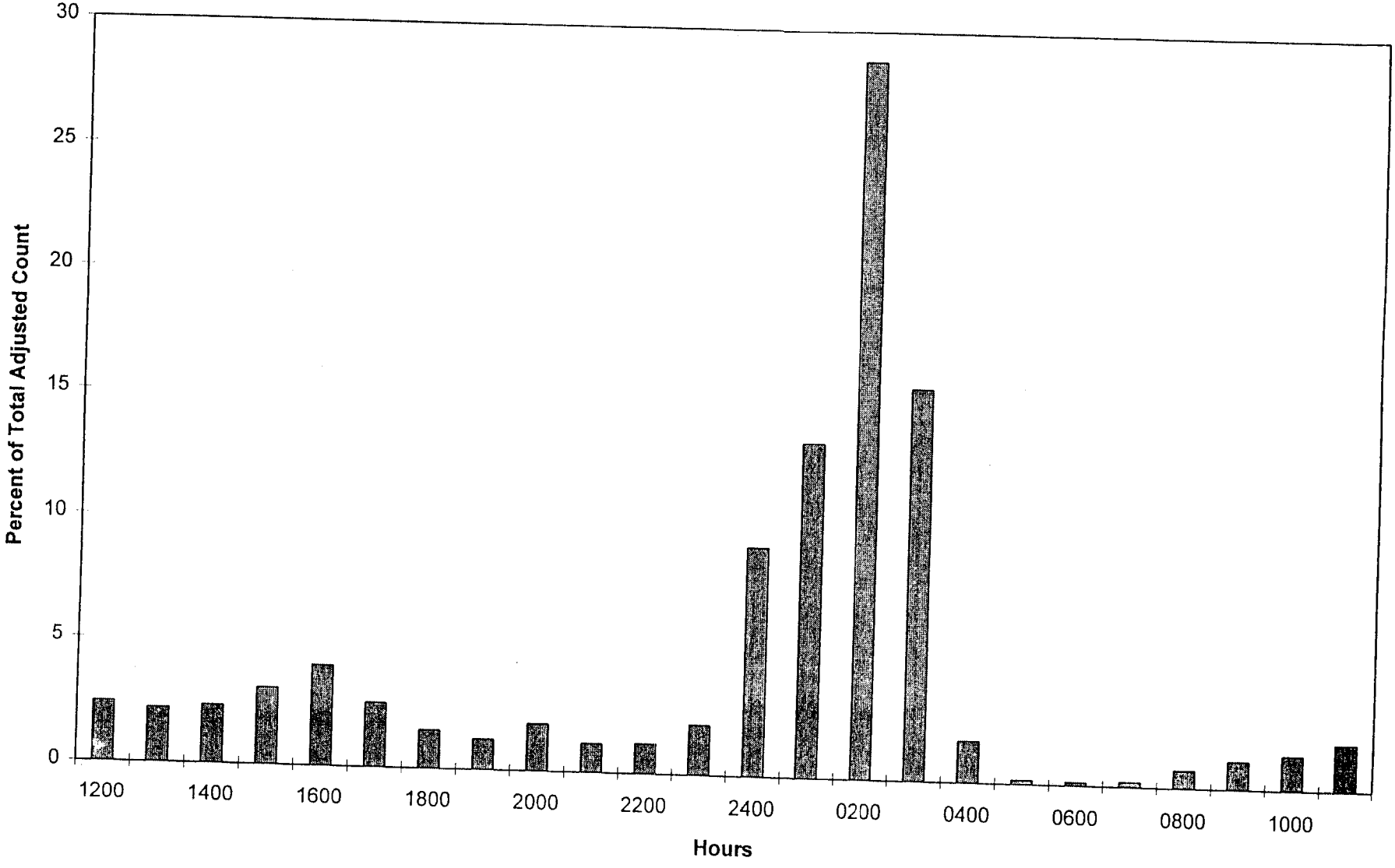


Figure 18. Percent of the total adjusted sonar count summarized by hour, Ugashik River smolt project, May 19 to June 11, 1996.

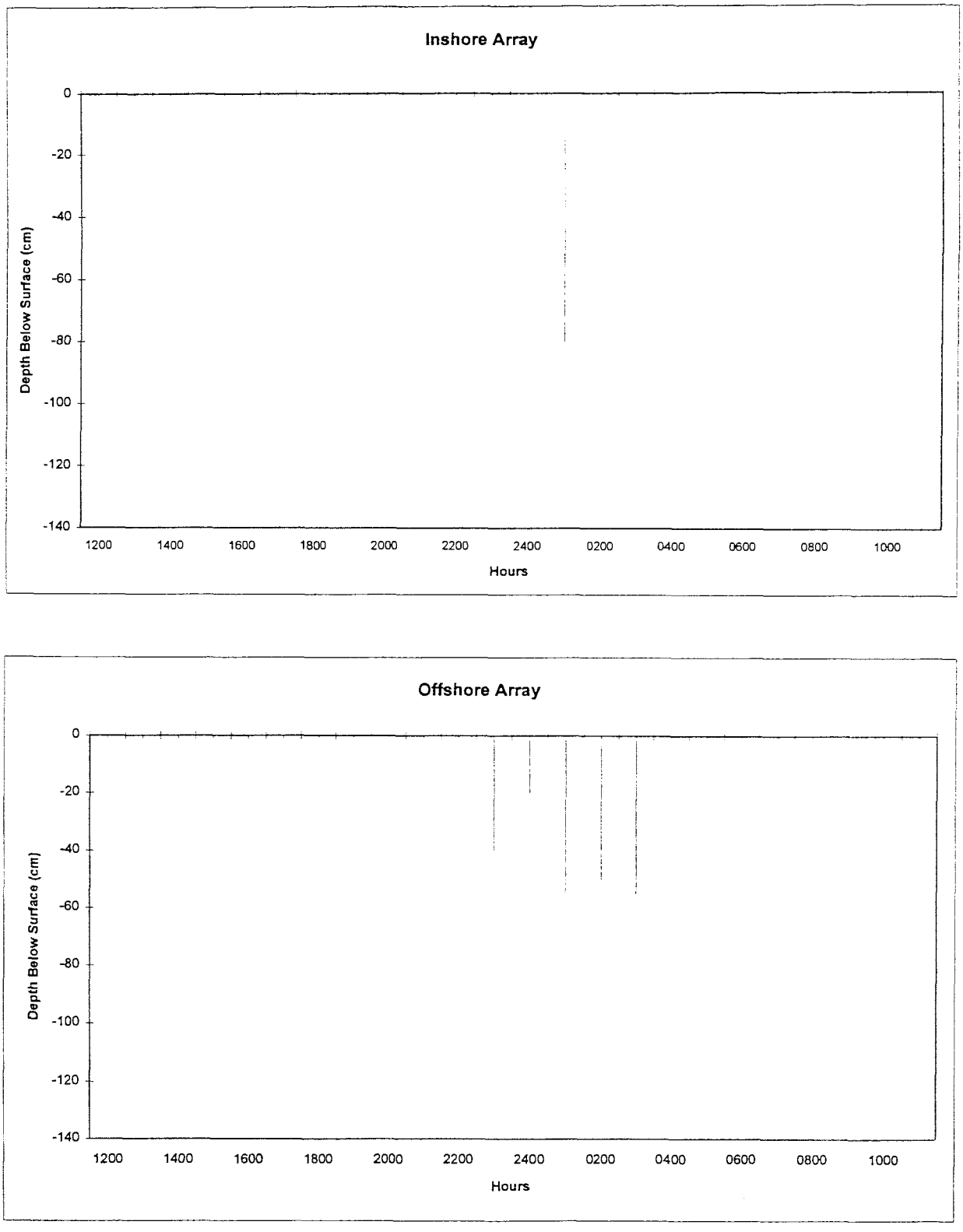


Figure 19. Depth of smolt passage data summarized by hour, Ugashik River, May 24 to June 10, 1996.

Appendix A.1. Ice-cover dates for Lake Iliamna, 1970-1996.

Winter of	Freeze-up Date [a] (dd-mmm)	Julian Day	Break-up Date [a] (dd-mmm)	Julian Day	Total Days of Ice Cover	Comments [a]
1969-1970	1-Jan	1				
1970-1971	7-Jan	7	16-Jun	167	159	Long, cold winter.
1971-1972			5-Jun	157		
1972-1973			25-May	145		
1973-1974			21-May	141		
1974-1975	26-Dec	-5	4-Jun	155	158	
1975-1976			7-May	128		
1976-1977	4-Feb	35	2-May	122	88	Partially open 30- Mar
1977-1978			11-May	131		80% open 02-May
1978-1979			3-May	123		50% open 28-Apr
1979-1980			3-May	124		
1980-1981						
1981-1982	9-Jan	9	25-May	145	136	Started to reopen 10-Feb
1982-1983						
1983-1984						Still open 19-Dec
1984-1985	11-Feb	42	5-Jun	157	114	50% open 29-May
1985-1986	18-Jan	18	12-May	132	114	
1986-1987	13-Feb [b]	44	23-Mar	86	40	Still not frozen up by 13-Feb
1987-1988	26-Jan	26				Began re-opening 24-Feb; 75% open 01-Apr
1988-1989	13-Jan	13				50% open 20-Apr
1989-1990	9-Jan	9	22-May	142	133	
1990-1991	7-Jan	7				
1991-1992	27-Jan	27	4-May	125	97	
1992-1993	22-Jan	22	3-May	123	101	
1993-1994	16-Feb	47	5-May	125	79	Ice jammed along west shore; trickled out until May 29
1994-1995	11-Jan [b]	11	22-May	142	131	Lake frozen briefly, Dec 19, then reopened. Lake 95% open by May 13
1995-1996	12-Jan	12	5-May	125	113	
Minimum	26-Dec		23-Mar		40	
Average	19-Jan	19	15-May	135	113	
Maximum	16-Feb		16-Jun		159	

[a] Most data is anecdotal, provided by pilots from local air charter companies (R. Russell, ADF&G retired, King Salmon, personal communication).

[b] Last date area was observed with open water; may have frozen over later.

Appendix A.2. Ice-cover dates for Becharof Lake, 1970-1996.

Winter of	Freeze-up Date [a] (dd-mmm)	Julian Day	Break-up Date [a] (dd-mmm)	Julian Day	Total Days of Ice Cover	Comments [a]
1969-1970						
1970-1971						Long, cold winter.
1971-1972						
1972-1973						
1973-1974						
1974-1975						
1975-1976			6-Apr	97		
1976-1977			6-Apr	96		Island Arm still frozen. Main basin opened earlier.
1977-1978						
1978-1979						
1979-1980						
1980-1981			13-May	133		May have opened earlier.
1981-1982			20-May	140		Still open 15-Dec. May have opened earlier than 20-May.
1982-1983	18-Jan	18				50% open 31-Mar
1983-1984	16-Jan [b]	16	16-May	137		Still open 16-Jan
1984-1985	11-Feb	42	3-May	123	82	
1985-1986	26-Feb	57	27-Apr	117	61	Still open 30-Jan
1986-1987	12-Mar [b]	71				Still open 12-Mar
1987-1988	24-Mar [b]	84				Still open 24-Mar
1988-1989	17-Jan	17	27-Apr	117	100	
1989-1990	21-Feb	52	25-Apr	115	64	
1990-1991	4-Feb	35	1-Apr	91	57	
1991-1992	27-Jan	27	10-May	131	103	
1992-1993	23-Jan	23	31-Mar	90	68	
1993-1994	25-Feb	56	4-Apr	94	39	
1994-1995	24-Jan	24	28-Apr	118	94	Wind driven ice lense blocked lake outlet on 19-May & 20-May
1995-1996	8-Jan	8	28-Mar	87	80	
Minimum	8-Jan		28-Mar		39	
Average	7-Feb	38	22-Apr	112	75	
Maximum	24-Mar		20-May		103	

[a] Most data is anecdotal, provided by pilots from local air charter companies (R. Russell, ADF&G retired, King Salmon, personal communication).

[b] Last date area was observed with open water; may have frozen over even later.

Appendix A.3. Ice-cover dates for Upper and Lower Ugashik Lakes, 1970-1996.

Winter of	Freeze-up Date [a] (dd-mmm)	Julian Day	Break-up Date [a] (dd-mmm)	Julian Day	Total Days of Ice Cover	Comments [a]
1969-1970						
1970-1971						Long, cold winter.
1971-1972						
1972-1973						
1973-1974						
1974-1975						
1975-1976						
1976-1977			6-Apr	96		
1977-1978						
1978-1979						
1979-1980						
1980-1981						Still open 16-Dec
1981-1982			12-May	132		
1982-1983	18-Jan	18				Partially open 31-Mar
1983-1984	16-Jan [b]	16				
1984-1985	11-Feb	42	14-May	134	93	
1985-1986	26-Feb	57	9-May	129	73	
1986-1987	12-Mar [b]	71				
1987-1988	9-Dec	-22	24-Mar	84	105	
1988-1989	17-Jan	17	10-May	130	113	
1989-1990	21-Feb	52	25-Apr	115	64	
1990-1991	8-Jan	8				
1991-1992	27-Jan	27	4-May	125	97	
1992-1993	20-Jan	20	31-Mar	90	71	
1993-1994	16-Feb	47	8-Apr	98	52	
1994-1995	24-Jan	24	28-Apr	118	94	
1995-1996	8-Jan	8	15-Apr	105	97	
Minimum	9-Dec		24-Mar		52	
Average	28-Jan	28	23-Apr	113	86	
Maximum	12-Mar		14-May		113	

[a] Most data is anecdotal, provided by pilots from local air charter companies (R. Russell, ADF&G retired, King Salmon, personal communication).

[b] Last date area was observed with open water; may have frozen over even later.

Appendix B.1. Kvichak River smolt fyke net catch log, 1996.

Date	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Day	Smolt Catch per Set	Smolt Catch per Day	CPUE [b]
5/19		1710	2130	260		0		0
		2130	2320	110		0		0
		2320	2350	30		0		0
	001	2350	0107	77	477	120	120	2
5/20		0110	0200	50		0		0
		0200	0330	90		0		0
	002	0330	0530	120	260	56	56	0
5/21		0030	0200	90		0		0
		0200	0400	120		0		0
	003	0400	0500	60		101		2
	004	0500	0630	90		200		2
		2048	2400	192		0		0
		2400	0200	120	672	0	301	0
5/22		0200	0400	120		0		0
	005	0400	0530	90		115		1
	006	0530	0600	30		200		7
		1630	2000	210		0		0
		2000	2350	230		0		0
		2350	0300	190	870	0	315	0
5/23		0300	0600	180	180	0	0	0
5/24		2245	0200	195	195	0	0	0
5/25		0200	0500	180		0		0
	007	1400	1530	90		120		1
		1535	1630	55		0		0
		1630	1745	75		3		0
	008	1745	1808	23		162		7
	009	1808	1938	90		400		4
	010	1938	2045	67		80		1
	011	2047	2150	63		300		5
	012	2152	2310	78	721	400	1465	5
5/26		0100	0300	120		0		0
		0300	0400	60		0		0
	013	0500	0505	5		50		10
	014	1620	1630	10		150		15
	015	1635	1645	10		100		10
	016	1650	1705	15		100		7
	017	1750	1845	55		500		9
	018	1845	1920	35		400		11
	019	1921	1950	29	339	300	1600	10
5/27	020	2055	2226	91		500		5
	021	2226	2324	58		250		4
	022	2325	0045	80	229	300	1050	4
5/28	023	0045	0115	30		150		5
	024	0115	0200	45		400		9
	025	0200	0300	60		2500		42
	026	1230	1300	30		1000		33
	027	1305	1315	10		150		15
	028	1320	1345	25		250		10
	029	1350	1400	10		150		15
	030	1430	1445	15		200		13
	031	1450	1500	10	235	200	5000	20

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Date	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Day	Smolt Catch per Set	Smolt Catch per Day	CPUE [b]
5/29		1545	1630	45		0		0
		1630	1745	75		0		0
		1745	1800	15		0		0
	032	1800	1925	85		75		1
	033	1926	2034	68		117		2
	034	2035	2150	75		500		7
	035	2151	2240	49		200		4
	036	2241	2340	59		114		2
	037	2341	0030	49	520	200	1206	4
5/30	038	1550	1710	80		150		2
	039	1715	1905	110		200		2
	040	1906	1920	14		92		7
	041	1921	2020	59		1000		17
	042	2021	2109	48		104		2
	043	2110	2120	10	321	200	1746	20
5/31	044	1255	1430	95		600		6
	045	1513	1620	67		200		3
	046	1621	1725	64		200		3
	047	1815	1905	50		1000		20
	048	1910	2005	55		500		9
	049	2010	2050	40	371	200	2700	5
6/01	050	1630	1745	75		99		1
	051	1746	1920	94		400		4
	052	1922	2008	46		400		9
	053	2010	2054	44		300		7
	054	2055	2150	55		400		7
	055	2151	2240	49	363	200	1799	4
6/02		1330	1505	95		0		0
	056	1505	1635	90		200		2
	057	1640	1735	55		200		4
	058	1740	1850	70		200		3
	059	1852	2000	68		200		3
		2002	2120	78		2		0
	060	2121	2232	71		100		1
	061	2233	2320	47	574	300	1202	6
6/03		1400	1530	60		0		0
		1530	1615	45		0		0
		1655	1745	50		0		0
		1745	1800	15		0		0
		1800	2115	195		2		0
		2115	2225	70		0		0
	062	2225	2400	95		40		0
		2400	0200	120	650	0	42	0
6/04		0200	0400	120		0		0
		0400	0600	120		0		0
		1410	1515	65		0		0
		1515	1630	75		0		0
		1630	1735	65		0		0
		1735	1800	25		0		0
	063	1800	2050	170		148		1
		2050	2225	95		0		0
		2225	2335	70		0		0
	064	2335	0200	145	950	100	248	1

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Date	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Day	Smolt Catch per Set	Smolt Catch per Day	CPUE [b]
6/05		0200	0400	120		0		0
	065	0400	0530	90		200		2
		1630	1745	75		0		0
	066	1745	1755	10		33		3
		1756	2115	199		0		0
		2116	2330	134		0		0
		2330	0200	150	778	0	233	0
6/06		0200	0400	120		0		0
		1500	1630	90		0		0
		1630	1730	60		0		0
		1730	1800	30		0		0
	067	1800	2050	170		159		1
	068	2050	2220	90		150		2
	069	2221	0005	104	664	80	389	1
6/07		0007	0135	88		0		0
		0135	0420	165		6		0
		1415	1455	40		0		0
		1455	1610	75		0		0
		1610	1730	80		0		0
		1730	1800	30		0		0
		1800	2145	225		0		0
	070	2145	0005	140	843	70	76	1
6/08	071	0005	0300	175		100		1
		0300	0500	120		0		0
		1530	1730	120		0		0
		1730	1800	30		0		0
		1800	2020	140		0		0
	072	2020	2250	150		300		2
	073	2250	0023	93	828	125	525	1
6/09	074	0028	0320	172		200		1
	075	0320	0600	160		78		0
	076	1255	1410	75		300		4
	077	1415	1500	45		200		4
	078	1505	1555	50		54		1
	079	1815	1905	50		400		8
	080	1906	1945	39		250		6
		1946	2023	37		1		0
	081	2025	2115	50	678	400	1883	8
6/10		1845	1925	40		3		0
	082	1925	2030	65		95		1
		2031	2130	59		0		0
		2130	2300	90		0		0
	083	2300	2400	60		104		2
	084	2400	0300	180	494	100	302	1
6/11	085	0300	0530	150		32		0
	086	1455	1610	75		48		1
	087	1615	1720	65		17		0
		1721	1800	39		0		0
	088	1800	1905	65		200		3
		1906	2000	54		0		0
		2000	2129	29		0		0
		2129	2300	91		15		0
		2300	0100	120	688	0	312	0
6/12		0100	0300	120		0		0
		0300	0530	150	270	0	0	0
Max				260	950	2500	5000	42
Avg				83	527	142	903	3
Min				5	180	0	0	0

[a] Military time - 24 hour clock (hhmm).

[b] CPUE = catch per unit effort

Appendix B.2. Egegik River smolt fyke net catch log, 1996.

Date	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Day	Smolt Catch per Set	Smolt Catch per Day	CPUE [b]
5/20		2307	0120	133	133	0	0	0
5/21	1	2353	0126	93	93	2	2	0
5/22	2	2349	0122	93	93	11	11	0
5/23		2344	0114	90	90	0	0	0
5/24	3	2352	0132	100	100	12	12	0
5/25	4	2345	0110	85	85	269	269	3
5/26	5	0112	0125	13		121		9
	6	0127	0137	10		147		15
	7	0139	0200	21	44	65	333	3
5/27	8	0010	0125	75		109		1
	9	0127	0210	43	118	45	154	1
5/28	10	0013	0100	47		183		4
	11	0102	0103	1		183		183
	12	0105	0107	2		94		47
	13	0109	0112	3		150		50
	14	0114	0118	4		107		27
	15	0120	0124	4	61	109	826	27
5/29	16	0020	0100	40		100		3
	17	0102	0105	3		100		33
	18	0107	0111	4		100		25
	19	0113	0130	17		100		6
	20	0132	0136	4		105		26
	21	0138	0142	4	72	101	606	25
5/30	22	0010	0106	56		105		2
	23	0108	0119	11		135		12
	24	0121	0130	9		99		11
	25	0132	0143	11		84		8
	26	0146	0205	19	106	47	470	2
5/31	27	0012	0205	113	113	52	52	0
6/01	28	0013	0200	107	107	22	22	0
6/02	29	0018	0200	102	102	38	38	0
6/03	30	0018	0200	102	102	24	24	0
6/04	31	0015	0200	105	105	7	7	0
6/05	32	0017	0159	102	102	23	23	0
6/06	33	0025	0204	99	99	13	13	0
6/07	34	0012	0200	108	108	14	14	0
6/08	35	0022	0159	97	97	3	3	0
6/09	36	0021	0200	99	99	9	9	0
6/10	37	0014	0202	108	108	81	81	1
6/11	38	0029	0154	85	85	50	50	1
6/12	39	0010	0200	110	110	2	2	0
Max				133	133	269	826	183
Avg				57	97	74	126	13
Min				1	44	0	0	0

[a] Military time - 24 hour clock (hhmm).

[b] CPUE = catch per unit effort

Appendix B.3. Ugashik River smolt fyke net catch log, 1996.

Date	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Hour	Total Time Fished (min) per Day	Smolt Catch per Set	Smolt Catch per Hour	Smolt Catch per Day	CPUE [b] per Set	CPUE [b] per Hour
5/20	1	2253	0115	142		142	30		30	0	
5/21	2	0120	0245	85			23			0	
	3	2255	2355	60	60		54			1	
	4	2400	0035	35	35	180	73	73	150	2	2
5/22	5	0040	0325	165			62			0	
	6	2240	0230	230		395	5		67	0	
5/23	7	2300	2345	45	45		200	200		4	4
	8	2350	0015	25		70	200		400	8	
5/24	9	0020	0030	10			118			12	
	10	0035	0055	20	130		95	213		5	17
	11	0100	0300	120			91			1	
	12	2310	2325	15			100			7	
	13	2330	2341	11			100			9	
	14	2346	2347	1	27	177	100	300	604	100	116
5/25	15	0005	0010	5	5		100	100		20	20
	16	0015	0115	60			114			2	
	17	0120	0200	40	40		100	100		3	3
	18	2300	2305	5			125			25	
	19	2310	2328	18			112			6	
	20	2333	2335	2			200			100	
	21	2340	2341	1			100			100	
	22	2346	2348	2			200			100	
	23	2353	2358	5	33	138	200	937	1251	40	371
5/26	24	2308	2322	14			93			7	
	25	2327	2342	15			81			5	
	26	2347	2349	2	31		150	324		75	87
	27	2354	0001	7		38	200		524	29	
5/27	28	0006	0008	2			300			150	
	29	0013	0020	7	9		150	450		21	171
	30	2311	2332	21			100			5	
	31	2337	2340	3			200			67	
	32	2345	2347	2			500			250	
	33	2354	2357	3	29	38	300	1100	1550	100	421
5/28	34	0002	0003	1			500			500	
	35	0007	0008	1	2		300	800		300	800
	36	2310	2320	10			100			10	
	37	2325	2327	2			150			75	
	38	2332	2335	3	15		300	550		100	185
	39	2340	0004	24		41	100		1450	4	
5/29	40	0009	0033	24	24		100			4	
	41	0038	0100	22			24	124		1	5
	42	2314	2330	16			150			9	
	43	2335	2341	6			200			33	
	44	2346	2352	6			200			33	
	45	2357	2359	2	30	76	200	750	874	100	176
5/30	46	0004	0006	2			100			50	
	47	0011	0014	3	5		200	300		67	117
	48	2308	2318	10			103			10	
	49	2323	2327	4			104			26	
	50	2332	2355	23	37	42	120	327	627	5	42

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Date	Cod End No.	Time [a] Set	Time [a] Pulled	Total Time Fished (min) per Set	Total Time Fished (min) per Hour	Total Time Fished (min) per Day	Smolt Catch per Set	Smolt Catch per Hour	Smolt Catch per Day	CPUE [b] per Set	CPUE [b] per Hour
5/31	51	0001	0010	9			102			11	
	52	0019	0025	6			200			33	
	53	0030	0044	14	29		200	502		14	59
	54	2315	2320	5			200			40	
	55	2325	2343	18	23		100	300		6	46
	56	2348	0020	32		84	106		908	3	
6/01	57	0028	0031	3			104			35	
	58	0036	0039	3			100			33	
	59	0044	0046	2	8		200	404		100	168
	60	2314	2354	40	40		73	73		2	2
	61	2359	0005	6		54	110		587	18	
6/02	62	0010	0018	8			111			14	
	63	0023	0028	5			100			20	
	64	0033	0043	10			100			10	
	65	0048	0052	4	27		103	414		26	70
	66	2315	0007	52		79	109		523	2	
6/03	67	0013	0022	9			94			10	
	68	0028	0033	5			150			30	
	69	0038	0040	2			100			50	
	70	0045	0048	3	19		200	544		67	157
	71	0053	0102	9		28	200		744	22	
6/04	72	0010	0037	27			112			4	
	73	0043	0046	3			100			33	
	74	0051	0053	2	32		300	512		150	187
	75	0104	0108	4			200			50	
	76	0113	0121	8			100			13	
	77	0126	0132	6	18	50	112	412	924	19	81
6/05	78	0013	0018	5			117			23	
	79	0023	0052	29	34		102	219		4	27
	80	0057	0103	6			121			20	
	81	0108	0117	9			100			11	
	82	0129	0135	6			200			33	
	83	0140	0144	4	19	59	400	700	1040	100	144
6/06	84	0016	0024	8			105			13	
	85	0029	0038	9			115			13	
	86	0047	0056	9	26		114	334		13	39
	87	0112	0138	26			104			4	
	88	0143	0200	17	43	69	69	173	507	4	8
6/07	89	0015	0038	23	23		126	126		5	5
	90	0043	0113	30		53	42		168	1	
6/11	91	0020	0041	21			117			6	
	92	0046	0053	7	28		100	217		14	20
	93	0104	0135	31			102			3	
	94	0140	0200	20	51	79	96	198	415	5	8
6/12	95	0015	0047	32	32		93	93		3	3
	96	0053	0101	8			200			25	
	97	0114	0130	16			100			6	
	98	0135	0145	5			110			22	
	99	0150	0200	10	31	71	74	284	577	7	36
Max				230	130	395	500	1100	1550	500	800
Avg				20	31	93	141	368	663	38	109
Min				1	2	28	5	73	30	0	2

[a] Military time - 24 hour clock (hhmm).

[b] CPUE = catch per unit effort

Appendix C.1. Kvichak River water velocity at the center smolt sonar array, 1987-1996.

	Water Velocity (ft/sec)										
Date	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1988-1995 Average
5/16											
5/17											
5/18							4.20			3.52	4.20
5/19			3.96								3.96
5/20											
5/21	4.96								4.82		4.82
5/22		5.38		5.01	4.27						4.89
5/23				4.99		3.43		4.27			4.23
5/24											
5/25											
5/26											
5/27							4.35			3.63	4.35
5/28			3.95								3.95
5/29						3.53			4.72		4.13
5/30											
5/31		5.50									5.50
6/01					4.47						4.47
6/02				5.37							5.37
6/03											
6/04								4.33		3.59	4.33
6/05											
6/06											
6/07						3.89					3.89
6/08		5.80							4.88		5.34
6/09							4.59				4.59
6/10			4.27	5.44	4.69						4.80
6/11											
6/12											
6/13							4.61	4.35		3.67	4.48
6/14											
6/15									4.90		4.90
Max		5.80	4.27	5.44	4.69	3.89	4.61	4.35	4.90	3.67	5.80
Avg	4.96	5.56	4.06	5.20	4.48	3.62	4.44	4.32	4.83	3.60	4.56
Min		5.38	3.95	4.99	4.27	3.43	4.20	4.27	4.72	3.52	3.43

Appendix C.2. Egegik River water velocity at the center smolt sonar array, 1984-1996.

	Water Velocity (ft/sec)													
Date	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1984-1995 Average
5/16														
5/17				2.15						2.37				2.26
5/18					2.63									2.63
5/19							2.50							2.50
5/20	1.89					2.00		2.00					1.50	1.96
5/21		1.16	1.83							2.30	2.68			1.99
5/22									1.58					1.58
5/23														
5/24									1.70			2.62		2.16
5/25					3.16								1.25	3.16
5/26			1.53	2.14			2.68							2.12
5/27											2.28			2.28
5/28						2.09				2.30				2.20
5/29								2.75						2.75
5/30														
5/31									2.02				1.28	2.02
6/01			1.76	2.30	2.90							2.75		2.43
6/02							2.73				2.43			2.58
6/03	1.82									2.30				2.06
6/04						2.30								2.30
6/05								2.85						2.85
6/06		1.16												1.16
6/07													0.90	
6/08												2.68		2.68
6/09									1.98		2.25			2.12
6/10			1.67	2.51	2.83									2.34
6/11														
6/12												2.40		2.40
6/13		1.32												1.32
6/14														
6/15														
Max	1.89	1.32	1.83	2.51	3.16	2.30	2.73	2.85	2.02	2.37	2.68	2.75	1.50	3.16
Avg	1.86	1.21	1.70	2.28	2.88	2.13	2.64	2.53	1.82	2.32	2.41	2.61	1.23	2.20
Min	1.82	1.16	1.53	2.14	2.63	2.00	2.50	2.00	1.58	2.30	2.25	2.40	0.90	1.16

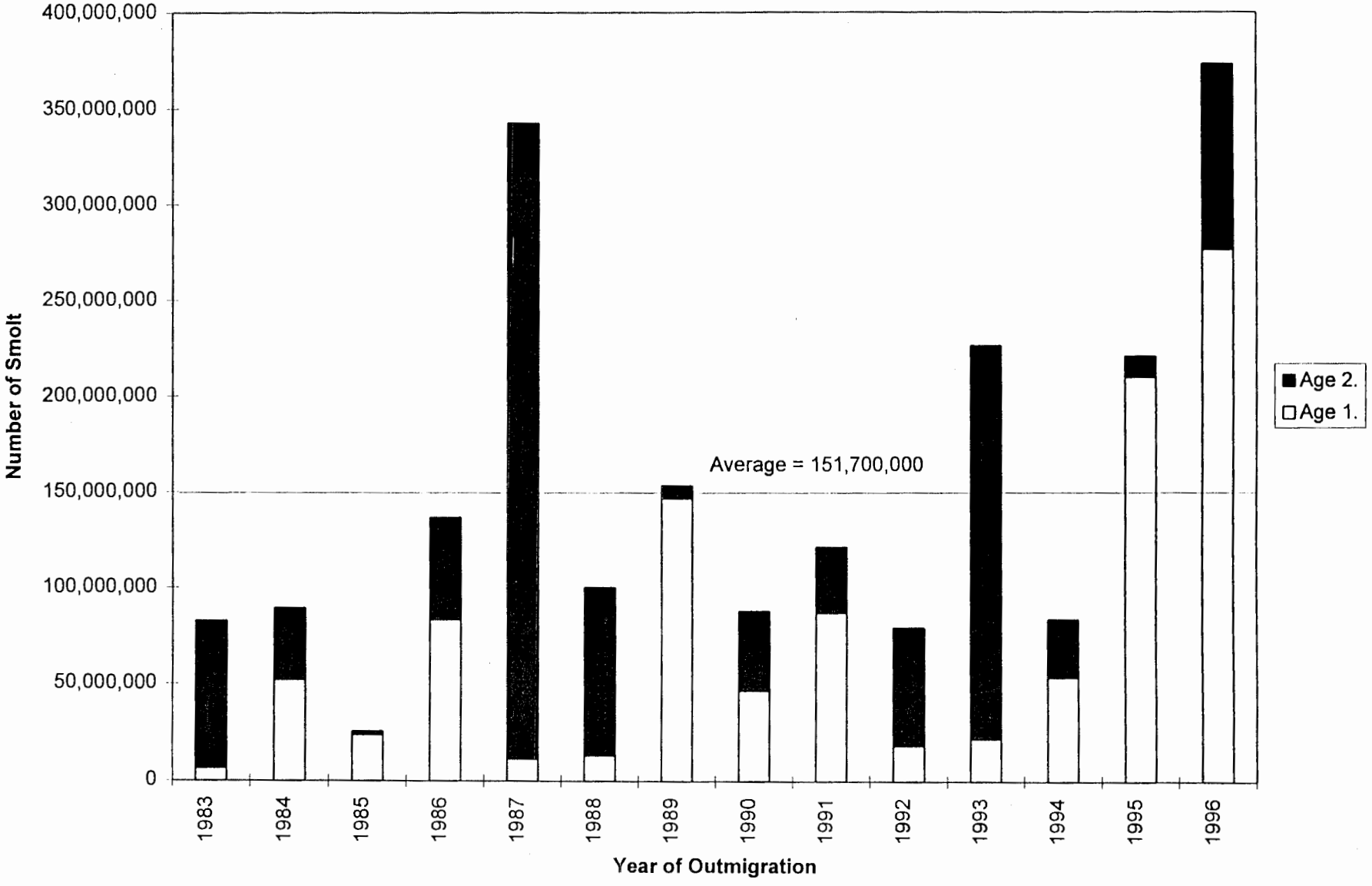
Appendix C.3. Ugashik River water velocity at the inshore smolt sonar array, 1983-1996.

	Water Velocity (ft/sec)														
Date	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992[a]	1993	1994	1995	1996	1983-1995 Average
5/16															
5/17					5.17	7.15					7.84				6.72
5/18															
5/19														3.91	
5/20								6.23	5.78			7.60			6.54
5/21															
5/22	8.00			3.16			4.13						9.48		6.19
5/23			4.10												4.10
5/24															
5/25	7.63										8.34				7.99
5/26												7.78		4.52	7.78
5/27															
5/28		5.56						6.73	7.82				8.93		7.26
5/29															
5/30							4.90								4.90
5/31				3.89											3.89
6/01											8.19				8.19
6/02							5.12					7.23		4.45	6.18
6/03															
6/04			4.93				6.17	6.84					8.72		6.66
6/05									7.70						7.70
6/06															
6/07															
6/08											8.34				8.34
6/09												7.04	7.53	4.47	7.29
6/10															
6/11				3.80											3.80
6/12							6.51	6.67							6.59
6/13															
6/14					4.94										4.94
6/15						6.95									6.95
Max	8.00	5.56	4.93	3.89	5.17	7.15	6.51	6.84	7.82		8.34	7.78	9.48	4.52	9.48
Avg	7.82	5.56	4.51	3.62	5.06	7.05	5.37	6.62	7.10		8.18	7.41	8.67	4.34	6.41
Min	7.63	5.56	4.10	3.16	4.94	6.95	4.13	6.23	5.78		7.84	7.04	7.53	3.91	3.16

[a] Project not conducted in 1992 due to lack of funding. No data collected.

Appendix D.1. Total smolt outmigration estimates for Kvichak River by outmigration year, 1983-1996.

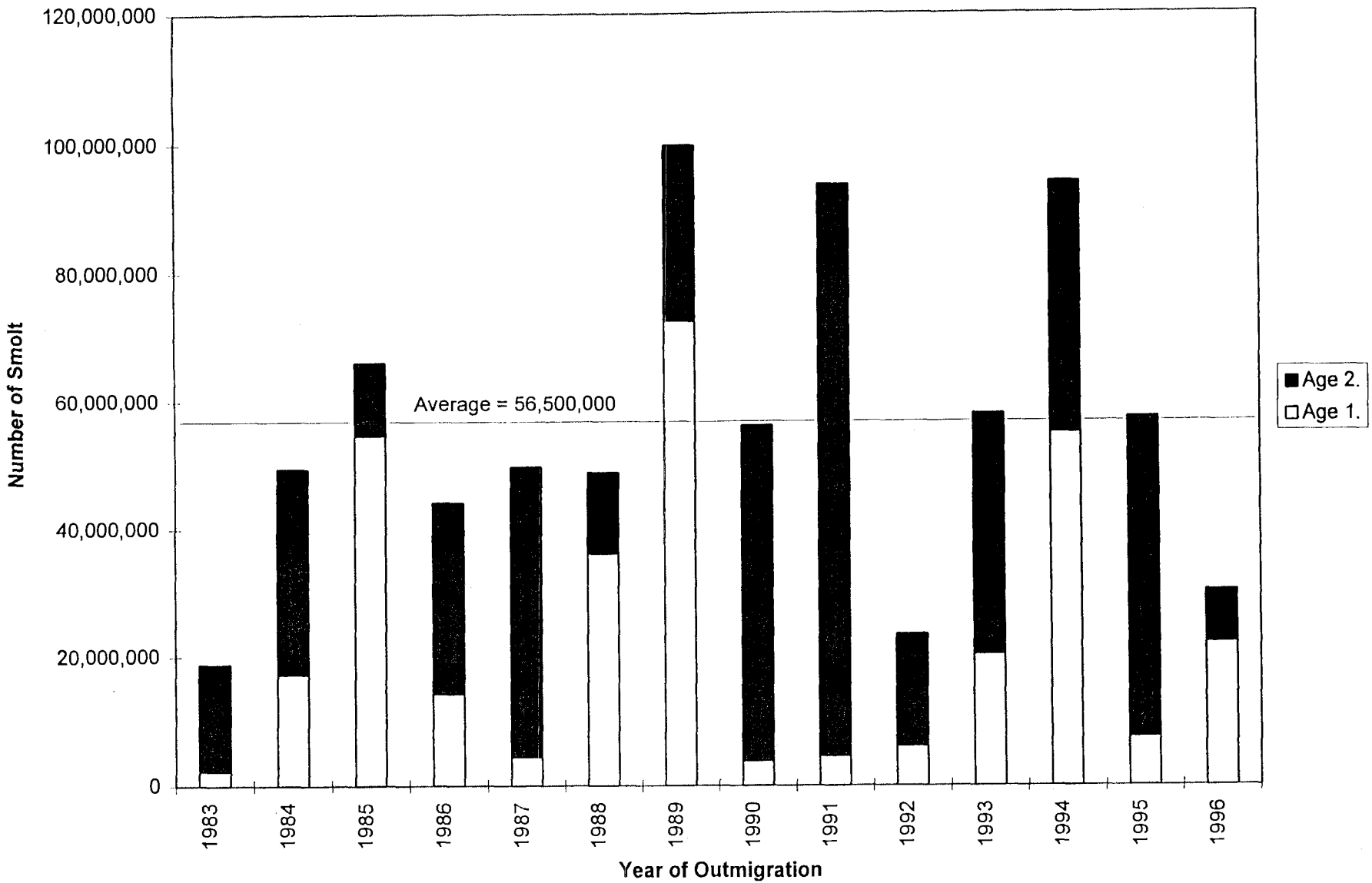
Year of Outmigration	Operating Dates	Total Days Operated	Cumulative Percent by Date			Peak Daily		Total Smolt Estimate	Comments
			10%	50%	90%	Date	Smolt Estimate		
1983	5/19-6/13	26	5/23	5/26	6/05	5/24	14,258,463	82,793,899	Ice Problems - 5/19-5/22 intermittent
1984	5/18-6/10	24	5/21	5/27	6/05	5/27	13,184,162	89,489,975	
1985	5/22-6/19	29	6/06	6/10	6/17	6/09	6,059,204	25,527,851	Ice Problems - 5/22-6/02, 6/06 intermittent, 6/03-6/05 continuous
1986	5/21-6/12	23	5/28	6/05	6/06	6/06	58,591,781	136,733,218	
1987	5/21-6/13	24	5/24	5/28	6/09	5/28	45,657,674	342,686,918	
1988	5/22-6/16	26	5/23	6/01	6/13	6/01	15,490,767	100,173,692	
1989	5/19-6/15	28	5/29	6/03	6/10	6/03	26,318,761	153,464,216	New Site Location - 1 km downstream from 1974-1988 site
1990	5/21-6/14	25	5/22	5/25	6/10	5/27	11,721,914	88,004,103	Ice Problems - prior to 5/21
1991	5/22-6/16	26	5/30	5/28	6/10	6/04	19,885,424	121,454,182	Ice Problems - 5/22-5/26 intermittent, 5/27-5/29 continuous
1992	5/23-6/13	22	5/25	5/22	6/03	5/28	18,838,144	79,490,008	Ice Problems - 5/19-5/22 continuous, 5/24-5/26, 5/31 intermittent
1993	5/18-6/11	25	5/19	5/24	5/31	5/31	44,155,479	226,407,888	
1994	5/28-6/15	19	5/31	6/05	6/11	6/05	11,705,421	83,845,472	Ice Problems - 5/17-5/28 continuous
1995	5/21-6/13	24	5/21	5/25	6/03	5/22	40,060,740	220,892,127	Ice Problems - 5/17-5/21 continuous
1983-95 Min		19	5/19	5/22	5/31	5/22	6,059,204	25,527,851	
1983-95 Avg		25	5/25	5/29	6/08	5/30	25,071,380	134,689,504	
1983-95 Max		29	6/06	6/10	6/17	6/09	58,591,781	342,686,918	
1996	5/18-6/12	26	5/24	5/28	5/31	5/28	78,544,749	373,166,532	



Appendix D.2. Age composition of smolt outmigration estimates for Kvichak River by outmigration year, 1983-1996.

Appendix D.3. Total smolt outmigration estimates for Egegik River by outmigration year, 1983-1996.

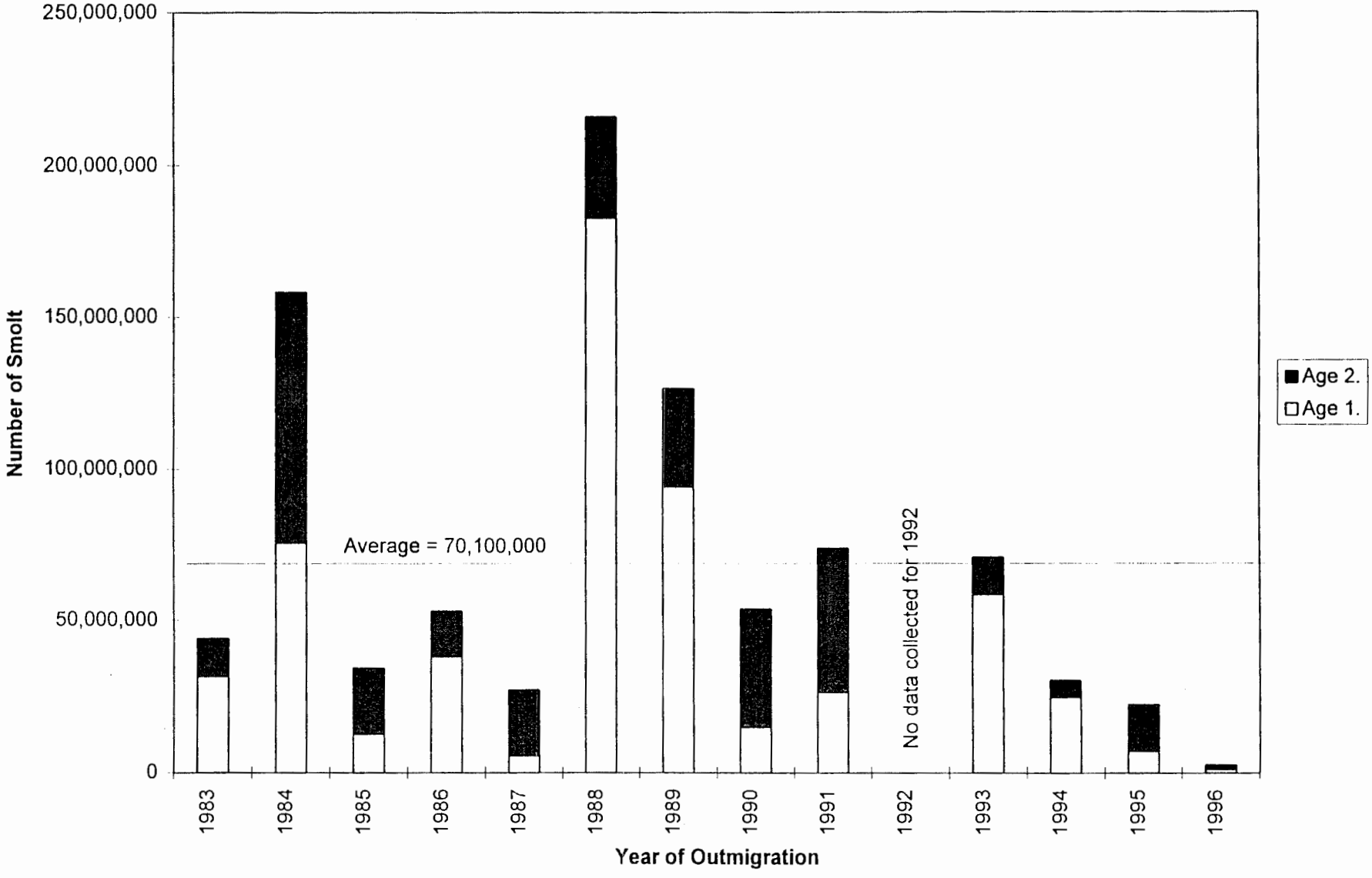
Year of Outmigration	Operating Dates	Total Days Operated	Cumulative Percent by Date			Peak Daily		Total Smolt Estimate	Comments
			10%	50%	90%	Date	Smolt Estimate		
1983	5/17-6/10	25	5/21	5/27	5/31	5/29	5,377,393	18,766,889	
1984	5/19-6/10	23	5/26	5/26	5/30	5/26	23,006,014	49,667,432	
1985	5/19-6/11	24	5/27	5/29	6/01	5/27	24,392,451	66,073,548	Ice Present - 5/17-5/22 intermittent
1986	5/18-6/11	25	5/27	5/29	6/03	5/29	10,079,789	44,197,865	Ice Present - 5/19-5/25 intermittent
1987	5/19-6/13	26	5/21	5/24	6/08	5/22	9,088,350	49,868,710	
1988	5/18-6/13	27	5/23	5/26	6/05	5/24	9,963,520	48,961,215	
1989	5/20-6/09	21	5/25	5/27	5/31	5/27	21,494,695	99,886,786	
1990	5/19-6/11	24	5/23	5/25	5/29	5/25	17,366,276	56,095,226	Fair Weather - 118 h disabled time
1991	5/21-6/11	22	5/25	5/28	6/07	6/04	17,890,595	94,077,988	Ice Problems - 5/17-5/18 continuous
1992	5/22-6/11	21	5/26	5/27	6/02	5/26	7,935,493	23,748,278	
1993	5/17-6/08	23	5/20	5/24	5/27	5/25	11,674,298	57,960,399	
1994	5/21-6/09	20	5/24	5/31	6/05	5/31	14,215,785	94,086,989	
1995	5/21-6/12	23	5/22	5/23	5/29	5/23	19,428,442	57,385,790	Ice Problems - 5/19-5/21 continuous
1983-95 Min		20	5/20	5/23	5/27	5/22	5,377,393	18,766,889	
1983-95 Avg		23	5/25	5/27	6/03	5/26	14,762,546	58,521,317	
1983-95 Max		27	5/29	6/01	6/09	6/04	24,392,451	99,886,786	
1996	5/19-6/12	25	5/24	5/25	5/29	5/24	10,043,411	31,270,793	



Appendix D.4. Age composition of smolt outmigration estimates for Egegik River by outmigration year, 1983-1996.

Appendix D.5. Total smolt outmigration estimates for Ugashik River by outmigration year, 1983-1996.

Year of Outmigration	Operating Dates	Total Days Operated	Cumulative Percent by Date			Peak Daily		Total Smolt Estimate	Comments
			10%	50%	90%	Date	Smolt Estimate		
1983	5/21-6/16	27	5/26	6/01	6/13	6/07	5,355,409	44,033,811	
1984	5/22-6/16	26	5/24	6/01	6/08	6/01	26,771,956	158,174,626	
1985	5/22-6/17	27	5/24	6/05	6/11	6/04	5,498,113	34,101,390	Ice Present - 5/17-5/21 intermittent
1986	5/21-6/13	24	5/30	6/02	6/10	5/30	9,142,549	53,076,253	
1987	5/17-6/13	28	5/21	6/03	6/06	6/03	4,944,521	26,947,225	
1988	5/17-6/13	28	5/28	6/06	6/10	6/07	55,816,902	215,968,015	
1989	5/22-6/15	25	5/25	5/31	6/09	5/25	22,376,115	126,298,122	
1990	5/20-6/13	25	5/26	5/30	6/07	5/29	13,459,723	53,627,347	Poor Weather - 199 h disabled time
1991	5/20-6/13	25	5/25	6/02	6/06	6/02	11,905,863	73,769,877	Poor Weather - 187 h disabled time
1992		0							
1993	5/17-6/11	26	5/26	5/30	6/06	5/26	12,360,357	70,747,074	Poor Weather - 264 h disabled time
1994	5/20-6/12	24	5/28	6/04	6/07	6/04	6,914,049	30,030,624	Good Weather - 44 h disabled time
1995	5/22-6/12	22	5/24	5/26	6/01	5/25	4,355,545	22,234,137	Excellent Weather - 21 h disabled time
1983-95 Min		0	5/21	5/26	6/01	5/25	4,355,545	22,234,137	
1983-95 Avg		24	5/26	6/01	6/07	6/01-02	14,908,425	75,750,708	
1983-95 Max		28	5/30	6/06	6/13	6/07	55,816,902	215,968,015	
1996	5/19-6/11	26	5/25	5/30	6/04	6/04	627,517	2,576,812	Fair Weather - 105 h disabled time



Appendix D.6. Age composition of smolt outmigration estimates for Ugashik River by outmigration year, 1983-1996.

Appendix E.3. Comparison of Ugashik River mean water temperatures at the start of the smolt sonar project and at the time of peak smolt passage, 1984-1996.

	Sonar Startup		Peak Smolt Passage	
Year	Smolt Day	Mean Water Temperature °C	Smolt Day	Mean Water Temperature °C
1984	22-May	4.8	1-Jun	6.5
1985	22-May	1.5	4-Jun	5.3
1986	21-May	4.0	30-May	5.0
1987	17-May	5.5	3-Jun	6.3
1988	17-May	3.5	7-Jun	7.3
1989	22-May	4.0	25-May	4.0
1990	20-May	3.0	29-May	6.3
1991	20-May	4.0	2-Jun	5.5
1992 [a]				
1993	17-May	6.0	26-May	7.0
1994	20-May	5.0	4-Jun	7.0
1995	22-May	4.5	25-May	5.0
Max		6.0		7.3
Avg		4.2		5.9
Min		1.5		4.0
1996	19-May	4.0	4-Jun	7.0

[a] Project not conducted. No data collected.

APPENDIX F. OVERVIEW OF THE 1996 UGASHIK RIVER SMOLT OUTMIGRATION

The following factors were investigated in order to analyze possible causes for the extremely low smolt outmigration estimate for the Ugashik River drainage in 1996.

Smolt Sonar Equipment

At 1600 hours on May 28 the Ugashik River smolt crew voiced concern about low sonar counts despite good fyke net catches the previous night (Appendix F.1). They reported seeing smolt passing the fyke net site that did not appear to register on the sonar counter. A boat test was conducted and it indicated that all transducers were functioning properly on both arrays. They wondered if the sonar counter could be under counting due to the low velocity of the river this year. The water velocity over the inshore array was measured at 3.9 fps (1.2 mps); this is 39% lower than the 1983-1995 mean water velocity of 6.4 fps (2.0 mps) (Appendix C.3).

The designer of the hydroacoustics equipment, Al Menin (Hydroacoustic Consulting, Sylmar, CA) was contacted immediately. He said that the low water velocity would not cause under counting of smolt. As long as the crew measured the water velocity and used the inverse of this measurement to set the river velocity gauge on their counter, the smolt counter would calibrate the smolt counts automatically according to the river velocity setting. However, he was concerned that the crew was catching and seeing smolt which were not being recorded on the sonar counter and he recommended sending them a replacement smolt counter immediately.

A float plane was dispatched from King Salmon to the Ugashik Smolt camp at 1830 hours on May 28 with a replacement smolt counter [4].

The original Ugashik smolt counter [5] was turned off and disconnected at 2030 hours on May 28 and the replacement counter was installed and tested at 2130 hours. However, the replacement sonar counter remained disabled until 1030 hours on May 29 due to false counts from high SE wind (20-25+ mph) and breaking waves in the river . When the replacement smolt counter was reactivated the results were not markedly different than what had been observed with the original smolt counter.

At 1415 hours on May 30 the replacement smolt counter was disabled for testing. The replacement counter and the original Ugashik counters were then subjected to the same boat and debris tests and the results were virtually the same. Since the original Ugashik smolt counter worked as well as the

[4] Bendix, Model 1983, Serial No. 832003
[5] Bendix, Model 1982, Serial No. 9320004

replacement, Al Menin recommended using the original Ugashik smolt counter for the remainder of the season.

At the conclusion of the 1996 Ugashik River smolt project the original Ugashik smolt counter was examined and tested by Al Menin. He found the counter to be properly calibrated and functioning well. Therefore, this ruled out problems with the smolt sonar counter as a cause of the low smolt counts in 1996.

Evaluation of the Relationship Between Hourly Sonar Counts and Fyke Net Catches

One of the primary reasons for concern about the accuracy of the Ugashik River smolt sonar counter during the 1996 field season was that on one or more occasions it appeared that more smolt were being caught in the fyke net than were being counted at the sonar site . Therefore we looked at the relationship between these two data sets for several years to see how they compared.

Plots of corresponding hourly sonar counts with hourly fyke net catch per unit efforts (CPUE) at Ugashik River by date from 1993 to 1996 were inconclusive (Appendices F.2 - F.5). It appeared that occasionally these two data sets would coincide, however, in many cases the trends in the hourly sonar counts were not reflected by a similar trend in the fyke net CPUE.

To analyze this relationship further, we produced scatter plots using hourly sonar counts as the independent variable and fyke net CPUE's as the dependent variable for Ugashik River smolt data from 1993 to 1996 (Appendices F.6 - F.9). The overall pattern in these scatter plots suggests no significant correlation between smolt sonar counts and fyke net CPUE's at $\alpha = 0.05$ (1993, $P = 0.28$; 1994, $P = 0.63$; 1995, $P = 0.40$; 1996, $P = 0.12$). One data point in the 1996 data set stood out as a possible outlier (e.g., 6772, 800). The analysis was repeated without the questionable data point and again we found no evidence of correlation ($P = 0.77$).

Based on information from 1993 to 1995, the lack of agreement between fyke net CPUE and sonar counts in 1996 is not unusual.

Comparison of Smolt Outmigration Timing Among Years

Next we looked at the timing of the 1996 Ugashik River smolt outmigration and compared it to past years (e.g., 1987-1995) which were enumerated with sonar.

A plot of the percent of the total adjusted sonar counts by day showed that the peak days of the 1996 smolt outmigration at Ugashik River fell within the range of dates when smolt have been most

abundant at the sonar site since 1987 (Appendix F.10). In past years, the highest daily smolt counts have all occurred between May 25 and June 7. In 1996, the highest daily counts were recorded between May 27 and June 4.

A plot of the total adjusted sonar counts as cumulative percents by day showed that the overall timing of the 1996 Ugashik River smolt outmigration did not differ greatly from the 1987-1995 mean (Appendix F.11). Historically 10% of the Ugashik River smolt outmigration were counted by May 25, 50% by June 1, and 90% by June 7. In 1996, 10% of the total Ugashik River smolt count was reached on May 25, 50% on May 30, and 90% on June 4.

A comparison of the percent of the total adjusted sonar counts by hour for the entire smolt counting season showed that the peak hourly counts for 1996 corresponded very well with the 1987-1995 mean (Appendix F.12). Historically the highest hourly smolt counts at Ugashik River have occurred between 2300 hours and 0400 hours . The peak hourly counts in 1996 happened between 2400 hours and 0300 hours.

Based on historic trend, the observed timing of the 1996 Ugashik River smolt outmigration did not differ substantially from what we have recorded in the past.

Climatological Factors Affecting Freshwater Survival

The freshwater survival of salmon eggs, fry, and smolt from the 1993 and 1994 brood years were probably affected by several climatic factors outlined below; however, we have no direct information indicating the magnitude or direction of the effect.

Air Temperature

According to air temperature data collected by the National Weather Service (1995; 1996a,b,c,d, e,f) the overall annual temperatures for King Salmon and vicinity from July through June in 1993-1994, 1994-1995, and 1995-1996 were 2.8 °F, 1.2 °F, and 2.5 °F warmer than the 30-year mean (Appendix F.13). Average monthly temperatures for the same time periods were also predominantly warmer than the 30-year mean (Appendix F.14). Some cooler months which may have impacted salmon eggs, fry, and smolt in the Ugashik River drainage were February and March 1994 (0.8 °F and 4.4 °F below average), October, November, and December 1994 (3.1 °F, 3.5 °F, and 3.1°F below average), March and November 1995 (6.5 °F and 4.4 °F below average), and February 1996 (1.1°F below average).

Air temperatures during the winter of 1993-1994 were generally mild. Seventy-five percent of the daily air temperatures between October 1993 and April 1994 were greater than or equal to the norm (Appendix F.15). Therefore, temperatures were primarily favorable for the production of salmon

eggs and fry for the 1993 brood year. Below normal temperatures which may have contributed to increased mortality of eggs were most prevalent in February and March. However the following four periods all had below normal air temperatures: from January 6-10 (5 d) temperatures ranged from -10 to -34 °F below normal, from February 12-23 (12 d) temperatures ranged from -9 to -23 °F below normal, from February 28 to March 5 (6 d) temperatures ranged from -18 to -30 °F below normal, and from March 14-21 (8 d) -10 to -21 °F below normal.

The winter of 1994-1995 had more severe temperatures. Between October 1994 and April 1995, 41% of the daily air temperatures were below normal (Appendix F.16). This cooler weather may have slowed the production of salmon eggs and fry for the 1994 brood year and created less favorable rearing conditions for age-1. fry from the 1993 brood year[6] . Below normal temperatures predominated in October, November, and March with intermittent periods of below normal temperatures occurring in December, January, and February. The following periods had below normal air temperatures which may have contributed to reduced freshwater survival of juvenile sockeye salmon in the Ugashik River drainage: from October 17-21 (5 d) temperatures ranged from -2 to -10 °F below normal, from October 27-31 (5 d) temperatures ranged from -8 to -17 °F below normal, from November 21 to December 1 (11 d) temperatures ranged from -7 to -28 °F below normal, from December 4-7 (4 d) temperatures ranged from -10 to -26 °F below normal, from December 15-23 (9 d) temperatures ranged from -7 to -24 °F below normal, from January 23-27 (5 d) temperatures ranged from -8 to -28 °F below normal, from February 18-23 (6 d) temperatures ranged from -8 to -28 °F below normal, and from March 11-24 (14 d) temperatures ranged from -7 to -33 °F below normal.

Air temperatures during the winter of 1995-1996 were milder than 1994-1995, but not as warm as 1993-1994. Between October 1995 and April 1996, 34% of the daily air temperatures were below normal (Appendix F.17). This cooler weather may have created less favorable rearing conditions for age-2. smolt from the 1993 brood year and age-1. smolt from the 1994 brood year [7]. Below normal temperatures predominated in November and February with intermittent periods of below normal temperatures in January. Above normal temperatures, favorable to smolt production, predominated in December, March, and April. The following periods had below normal air temperatures which may have contributed to reduced freshwater survival of juvenile sockeye salmon in the Ugashik River drainage: from October 17-21 (5 d) temperatures ranged from -2 to -10 °F below normal, from October 27-31 (5 d) temperatures ranged from -8 to -17 °F below normal, from November 21 to December 1 (11 d) temperatures ranged from -7 to -28 °F below normal, from December 4-7 (4 d) temperatures ranged from -10 to -26 °F below normal, from December 15-23 (9 d) temperatures ranged from -7 to -24 °F below normal, from January 23-27 (5 d) temperatures ranged from -8 to -28 °F below normal, from February 18-23 (6 d) temperatures

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[6] In 1995, 31% of the estimated 2.2 million smolt that outmigrated from Ugashik River were Age-1. smolt from the 1993 brood year (Crawford and Cross 1996). These smolt were 2% larger and 15% heavier than the 1958-1994 means. Therefore, negative impacts upon these smolt from cold winter temperatures were not apparent from the size and condition of the survivors.

[7] Again the negative impacts of winter temperatures on these rearing fry were not apparent from the size and condition of the surviving smolt which outmigrated during the spring of 1996. Age-1. smolt (1994 brood year) were 15% larger and 50% heavier than the 1958-1995 average; age-2. smolt (1993 brood year) were 6% larger and 16% heavier than average.

ranged from -8 to -28 °F below normal, and from March 11-24 (14 d) temperatures ranged from -7 to -33 °F below normal.

Precipitation

Precipitation data collected by the National Weather Service (1995; 1996a,b,c,d,e,f) for King Salmon and vicinity indicate that the periods from July through June in 1993-1994, 1994-1995, and 1995-1996 differed from the 30-year mean annual precipitation of 19.6 in by +23%, +17%, and -11% (Appendix F.18).

Average monthly precipitation's during the 1993-1994 season were greater than or equal to the 30-year mean in 9 out of 12 months (Appendix F.19). The months in which precipitation probably had the greatest impact upon freshwater survival of sockeye salmon in the Ugashik River system were July, September, and November. The average monthly precipitation for July was 1.01 in, 55% less than the 30-year mean. This coupled with the fact that the precipitation for April, May, and June were also well below the 30-year average suggest that access to and availability of suitable salmon spawning habitat may have been reduced at this time due to low water levels. The average monthly precipitation for September was 4.53 in and for November was 3.00 in, 72% greater and 90% greater than and the 30-year mean, respectively. These increases in precipitation may have caused some fall flooding which could have displaced spawning adult salmon and/or scoured incubating salmon eggs from existing redds. However, we have no reports or first hand knowledge of significant flooding in the area.

Average monthly precipitation's during the 1994-1995 season were greater than or equal to the 30-year mean in 8 out of 12 months (Appendix F.19). The month in which precipitation probably had the greatest impact upon freshwater survival of sockeye salmon in the Ugashik River system was July. The average monthly precipitation for July was 3.77 in, 69% greater than the 30-year mean. The increase in precipitation may have caused some flooding however we have no direct information that significant flooding occurred. If flooding did occur it would probably have more impact on the spawning success of adult salmon depositing egg for the 1994 brood year than the age-1. fry from the 1993 brood year rearing in Upper and Lower Ugashik Lakes.

Average monthly precipitation's during the 1995-1996 season were less than the 30-year mean in 8 out of 12 months (Appendix F.19). The months in which low precipitation may have had the greatest impacts upon freshwater survival of sockeye salmon in the Ugashik River system were August, October, November, December, and March. The average monthly precipitation for August was 4.73 in, 57% greater than the 30-year mean. The average monthly precipitation for October, November, December, and March were 1.46 in, 0.13 in, 0.14 in, and 0.38 in respectively. The precipitation for these months were 30%, 92%, 90%, and 60% less than their 30-year mean. It is unknown how this increase followed by decreases in precipitation may have effected the age-1. (1994 brood year) and -2. (1993 brood year) fry rearing in Upper and Lower Ugashik Lakes.

Snowfall

Snowfall data collected for King Salmon and vicinity by the National Weather Service (1995; 1996a,b,c,d,e,f) indicate that the periods from July through June in 1993-1994, 1994-1995, and 1995-1996 differed from the 30-year mean annual precipitation of 46.8 in by +35%, +12%, and -45% (Appendix F.20).

Average monthly snowfalls during the winter of 1993-1994 were favorable for the freshwater survival of sockeye salmon in the Ugashik River system (Appendix F.21). The average monthly snowfall during October and November were slightly less than normal, however the above normal temperatures during this time probably canceled any negative effects (Appendix F.15). The 28.4 in of snow that fell in December was the largest snowfall on record for this month. This large snowfall at the beginning of the winter plus additional snowfall received in January, March, and April provided an excellent insulating layer which would help protect developing salmon eggs and emerging fry from sharp changes in temperature.

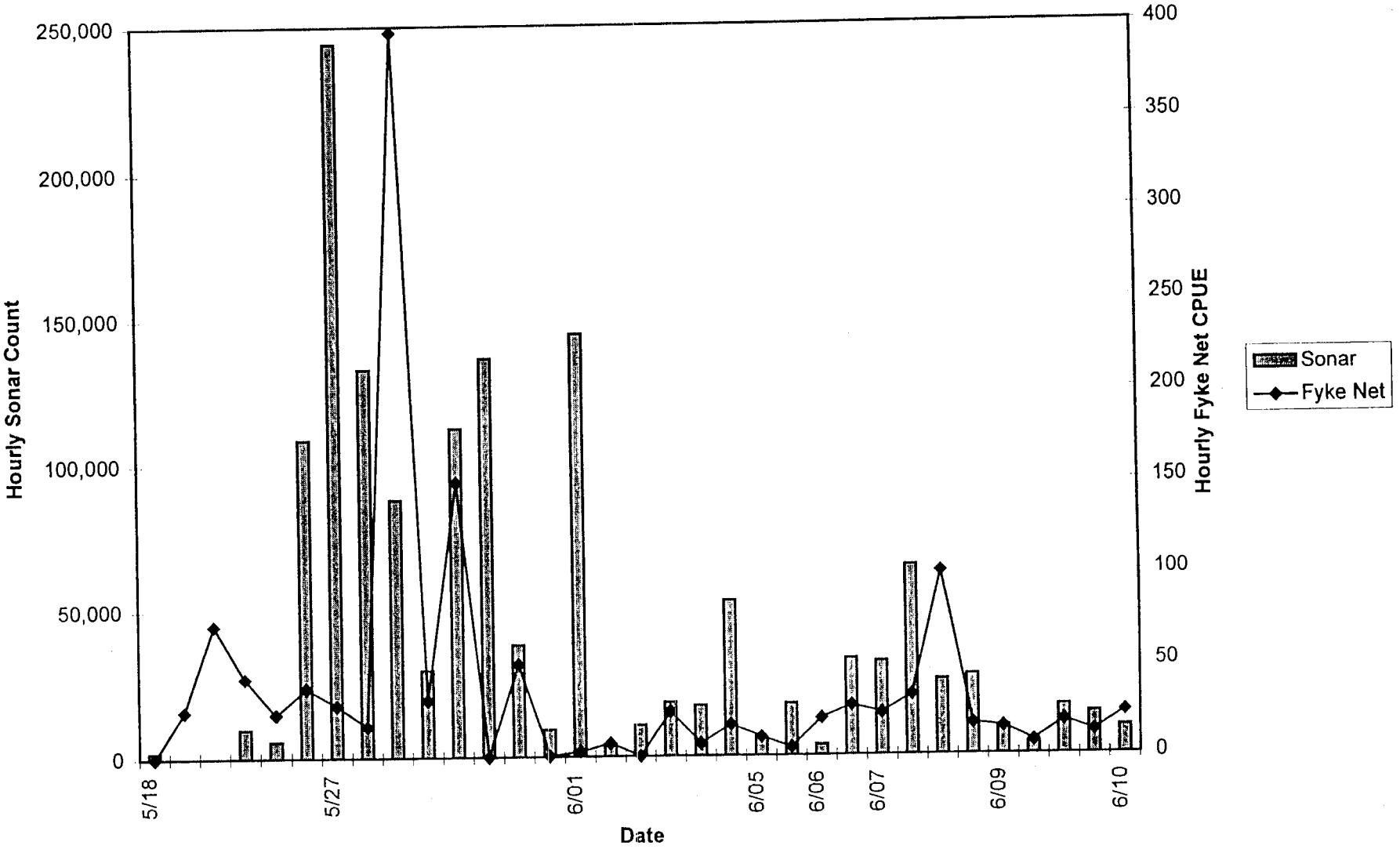
Average monthly snowfall during the winter of 1994-1995 was somewhat different than that of 1993-1994 (Appendix F.21). This winter most of the snow fell early with above normal snowfalls in October (8.4 in), November (17.9 in) and December (16.0 in). The monthly snowfall for the remainder of the winter was below normal, however the insulating qualities of the early snowfall probably protected developing salmon eggs and emerging and rearing fry.

Snowfall during the winter of 1995-1996 season was sparse (Appendix F.21). The average monthly snowfall for October, November, December, January, and March , were -38%, -66%, -83%, -69%, and -76% respectively, below the 30-year mean. Snowfall in March, April, and May was normal. It is unknown how the lack of insulating snow in the early half of the winter may have affected the age-1. (1994 brood year) and -2. (1993 brood year) fry rearing in Upper and Lower Ugashik Lakes.

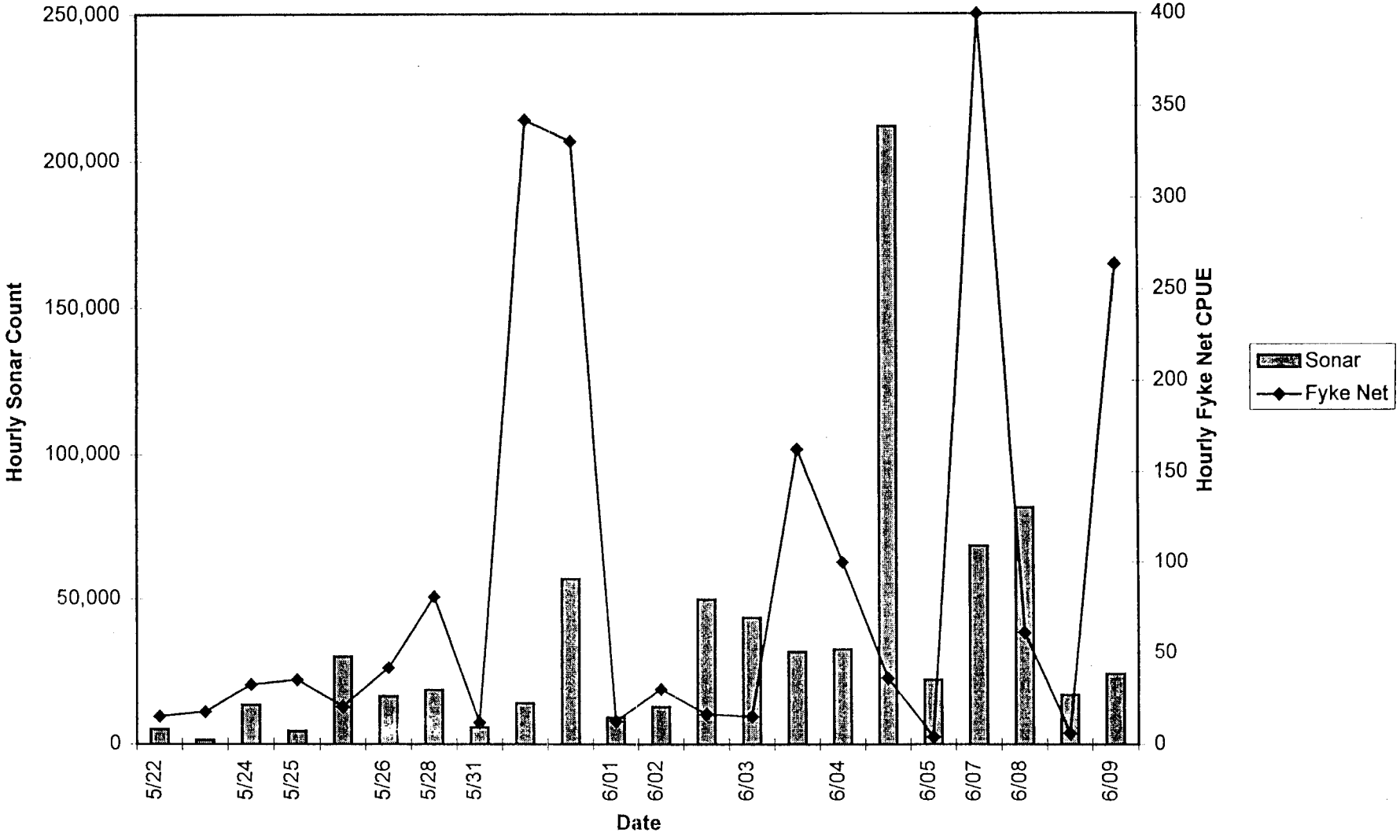
Appendix F.1. Comparison of fyke net catch per unit effort data with corresponding hourly sonar counts at Ugashik River, 1996.

Fyke Net							Smolt Sonar		
Date	Cod End Nos.	Time Set	Time Pulled	Total Time Fished (min) per Hour	Total Catch per Hour	Total CPUE per Hour	Date	Hour	Total Hourly Count
							Date		Sonar
5/21	4	2400	0035	35	73	2	5/20	2400	238
5/23	7	2300	2345	45	200	4	5/23	2300	911 [a]
5/24	9-10	0020	0055	130	213	17		2400	3,569
	12-14	2310	2347	27	300	116	5/24	2300	2,180
5/25	15	0005	0010	5	100	20		2400	6,046
	17	0120	0200	40	100	3	5/25	0100	2,789
	18-23	2300	2358	33	937	371		2300	229
5/26	24-26	2308	2349	31	324	87	5/26	2300	40
5/27	28-29	0006	0020	9	450	171		2400	1,017
	30-33	2311	2357	29	1100	421	5/27	2300	315
5/28	34-35	0002	0008	2	800	800		2400	6,772
	36-38	2310	2335	15	550	185	5/28	2300	284 [a]
5/29	40-41	0009	0100	24	124	5		2400	3,846 [a]
	42-45	2314	2359	30	750	176	5/29	2300	491
5/30	46-47	0004	0014	5	300	117		2400	6,854
	48-50	2308	2355	37	327	42	5/30	2300	291
5/31	51-53	0001	0044	29	502	59		2400	742
	54-55	2315	2343	23	300	46	5/31	2300	668
6/01	57-59	0028	0046	8	404	168		2400	1,655
	60	2314	2354	40	73	2	6/01	2300	350
6/02	62-65	0010	0052	27	414	70		2400	744
6/03	67-70	0013	0048	19	544	157	6/02	2400	545
6/04	72-74	0010	0053	32	512	187	6/03	2400	1,022
	75-77	0104	0132	18	412	81		0100	4,269
6/05	78-79	0013	0052	34	219	27	6/04	2400	1,078
	81-83	0108	0144	19	700	144	6/05	0100	8,333
6/06	84-86	0016	0056	26	334	39		2400	107
	87-88	0112	0200	43	173	8	6/06	0100	222
6/07	89	0015	0038	23	126	5		2400	137
6/11	91-92	0020	0053	28	217	20	6/10	2400	392
	93-94	0104	0200	51	198	8	6/11	0100	644
6/12	95	0015	0047	32	93	3		2400	277
	97-99	0114	0200	31	284	36	6/12	0100	1,153
		Max		130	1100	800			8,333
		Avg		30	368	109			1,764
		Min		2	73	2			40

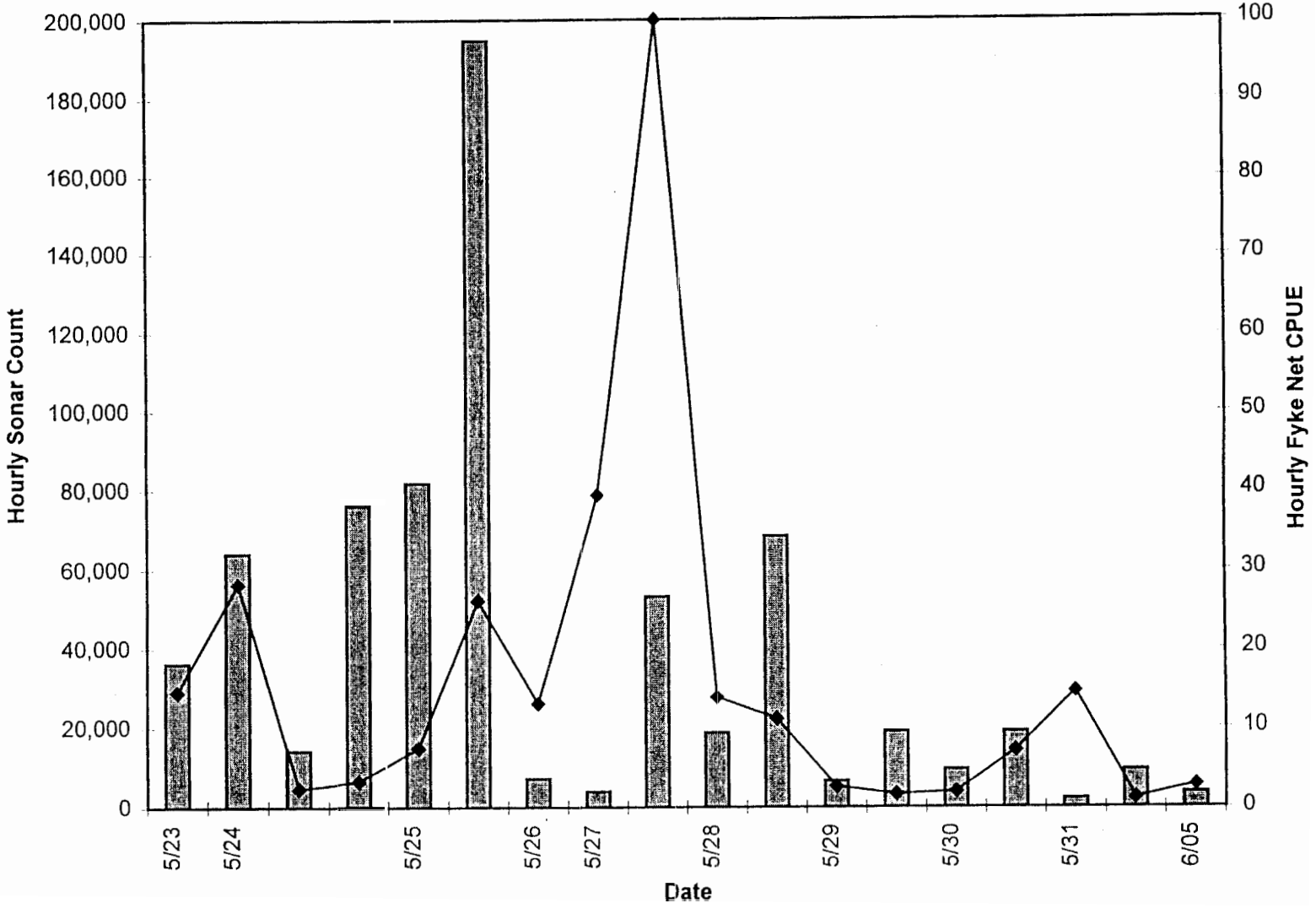
[a] Interpolated



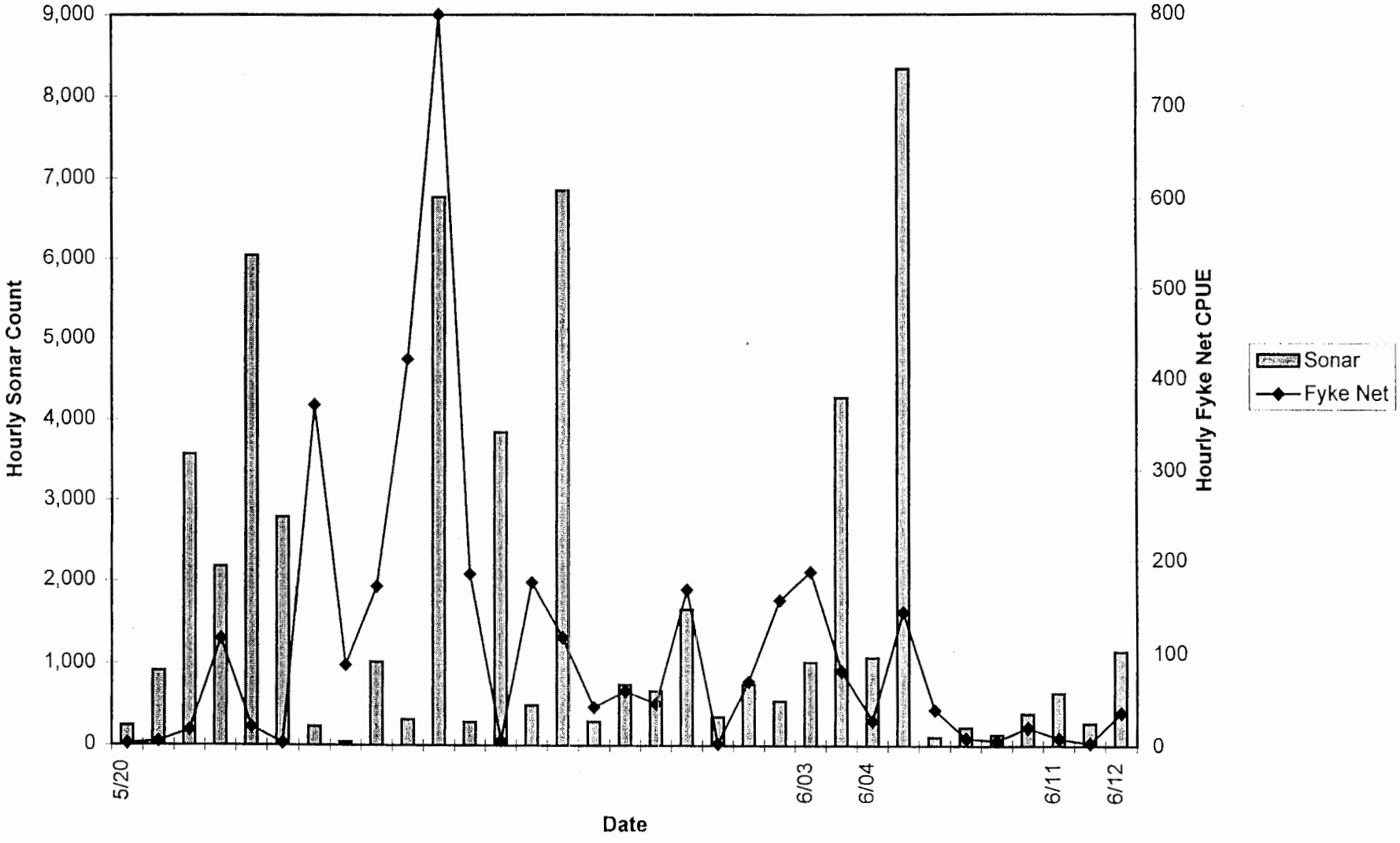
Appendix F.2. Comparison of 1993 Ugashik River smolt sonar counts with corresponding hourly fyke net catch per unit effort (CPUE) data.



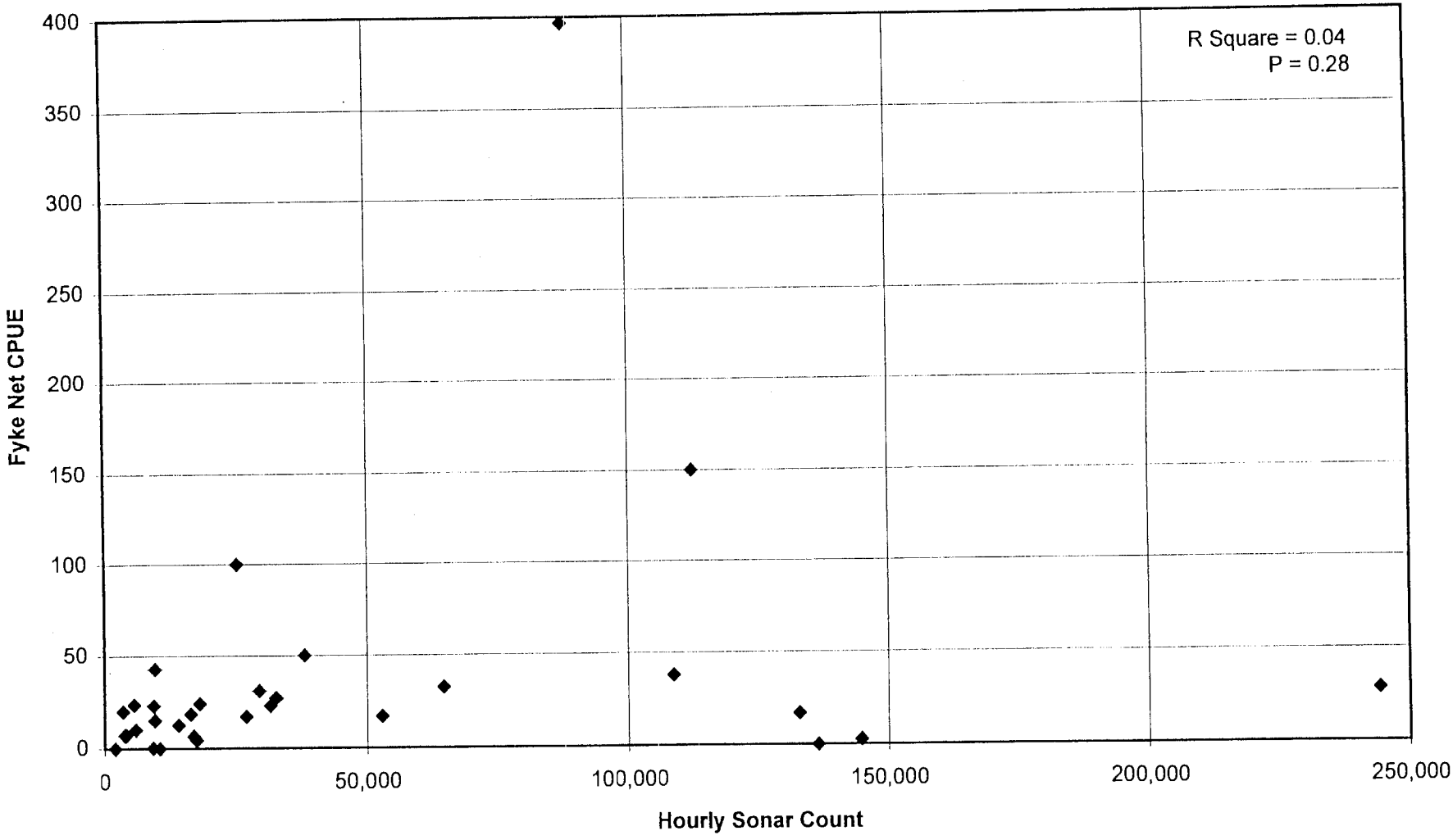
Appendix F.3. Comparison of 1994 Ugashik River smolt sonar counts with corresponding hourly fyke net catch per unit effort (CPUE) data.



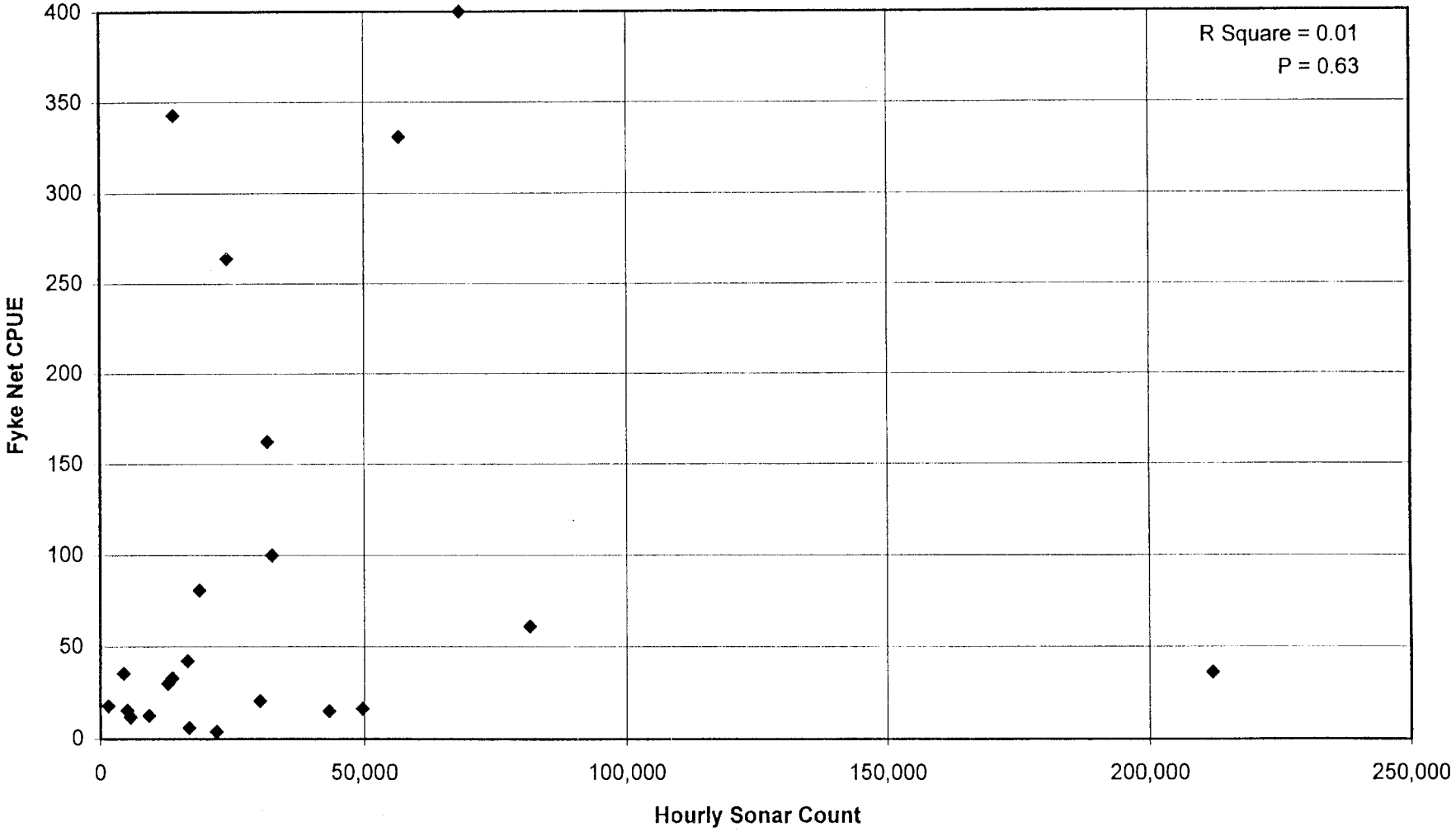
Appendix F.4 Comparison of 1995 Ugashik River smolt sonar counts with corresponding hourly fyke net catch per unit effort (CPUE) data.



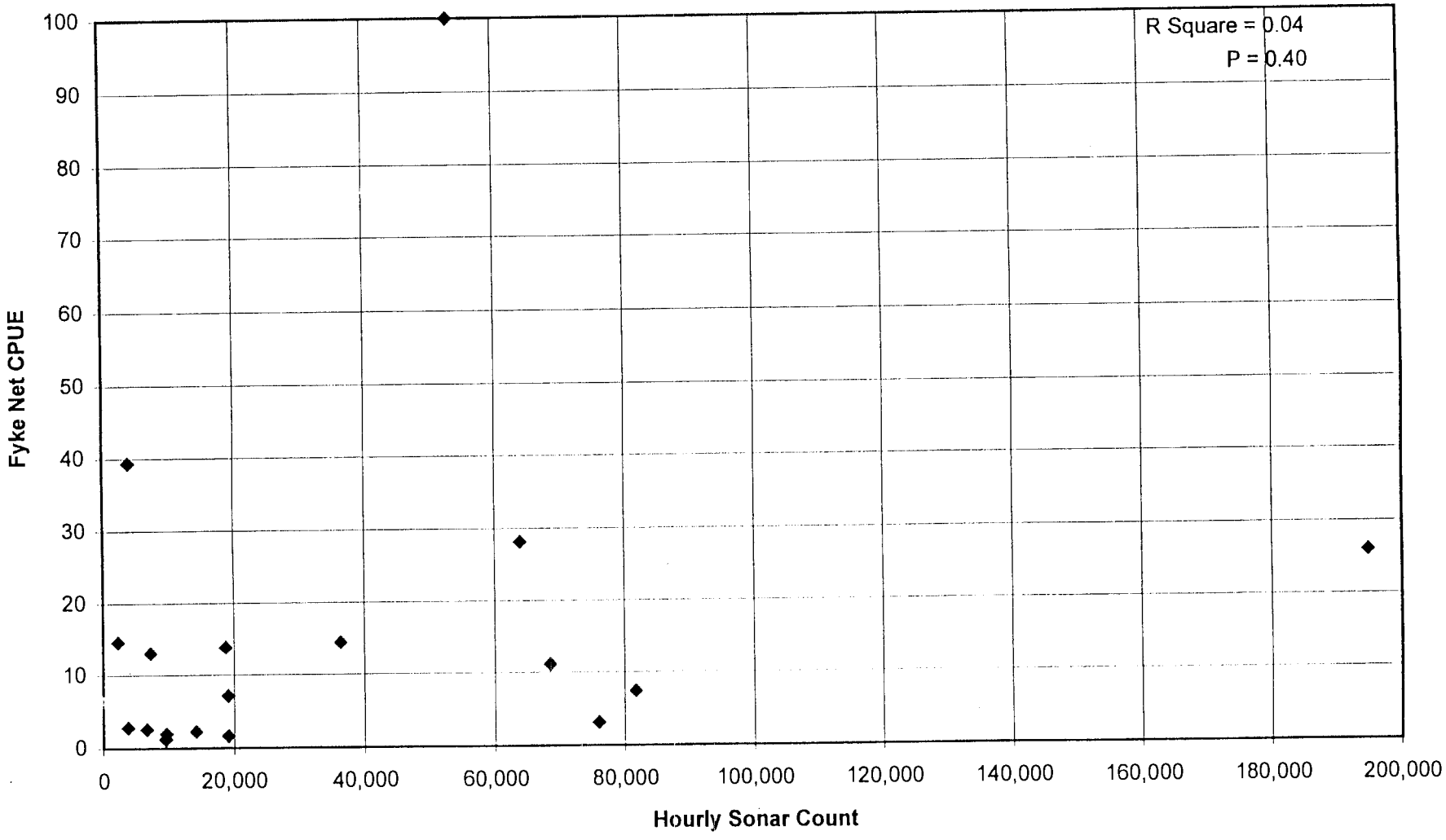
Appendix F.5. Comparison of 1996 Ugashik River smolt sonar counts with corresponding hourly fyke net catch per unit effort (CPUE) data.



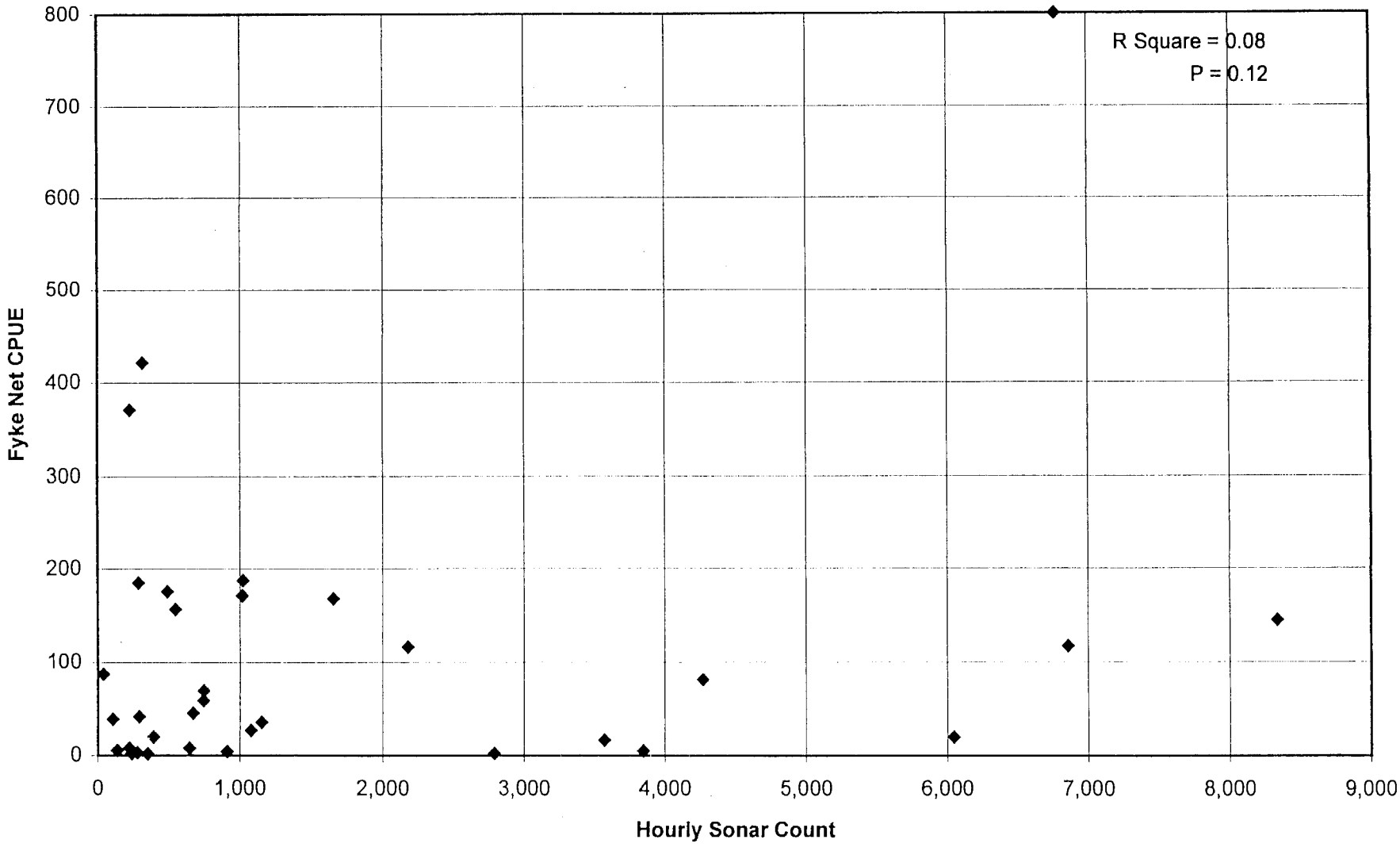
Appendix F.6. Scatter plot of 1993 Ugashik River smolt fyke net catch per unit effort (CPUE) data versus corresponding hourly sonar counts.



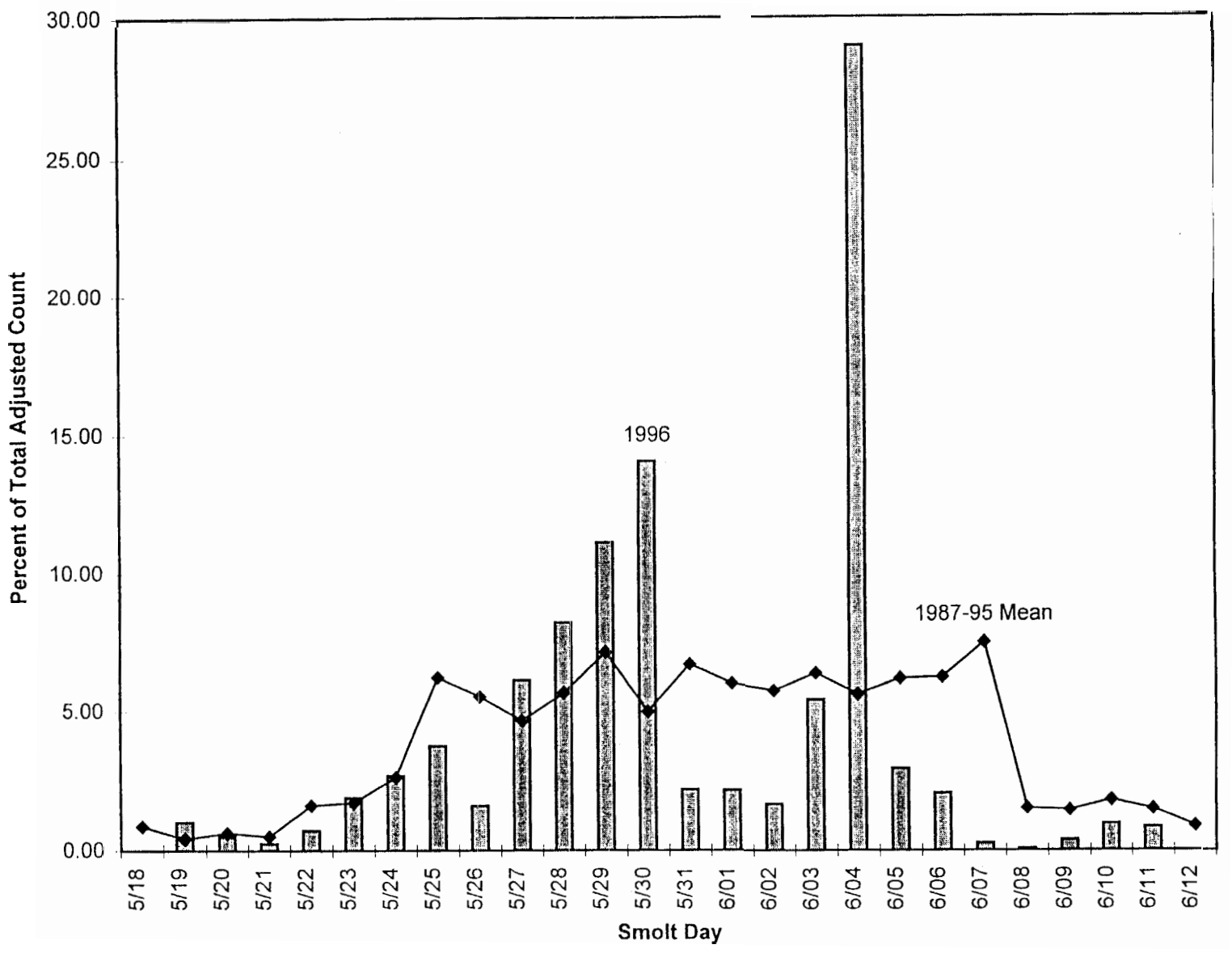
Appendix F.7. Scatter plot of 1994 Ugashik River smolt fyke net catch per unit effort (CPUE) data versus corresponding hourly sonar counts.



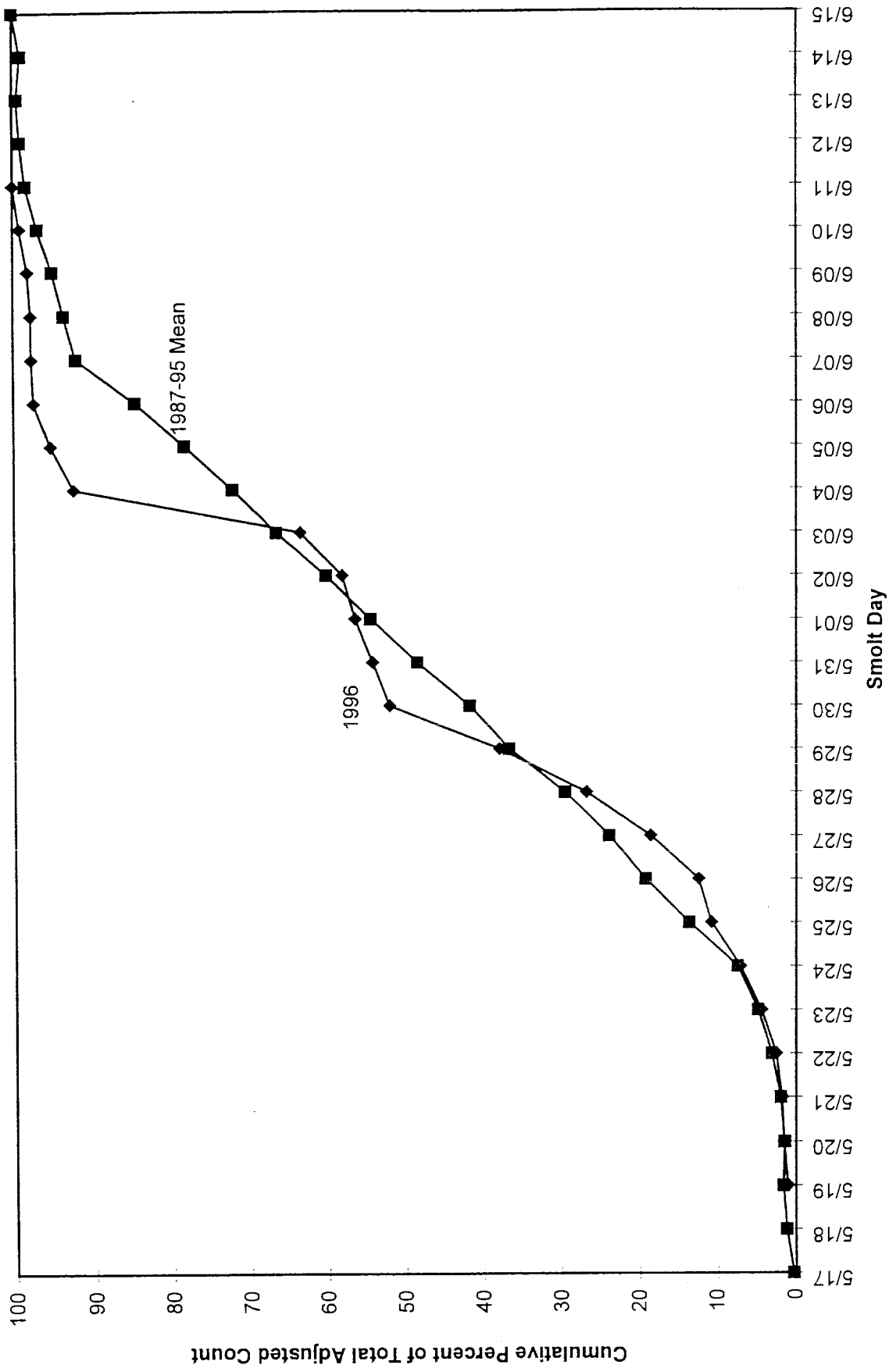
Appendix F.8. Scatter plot of 1995 Ugashik River smolt fyke net catch per unit effort (CPUE) data versus corresponding hourly sonar counts.



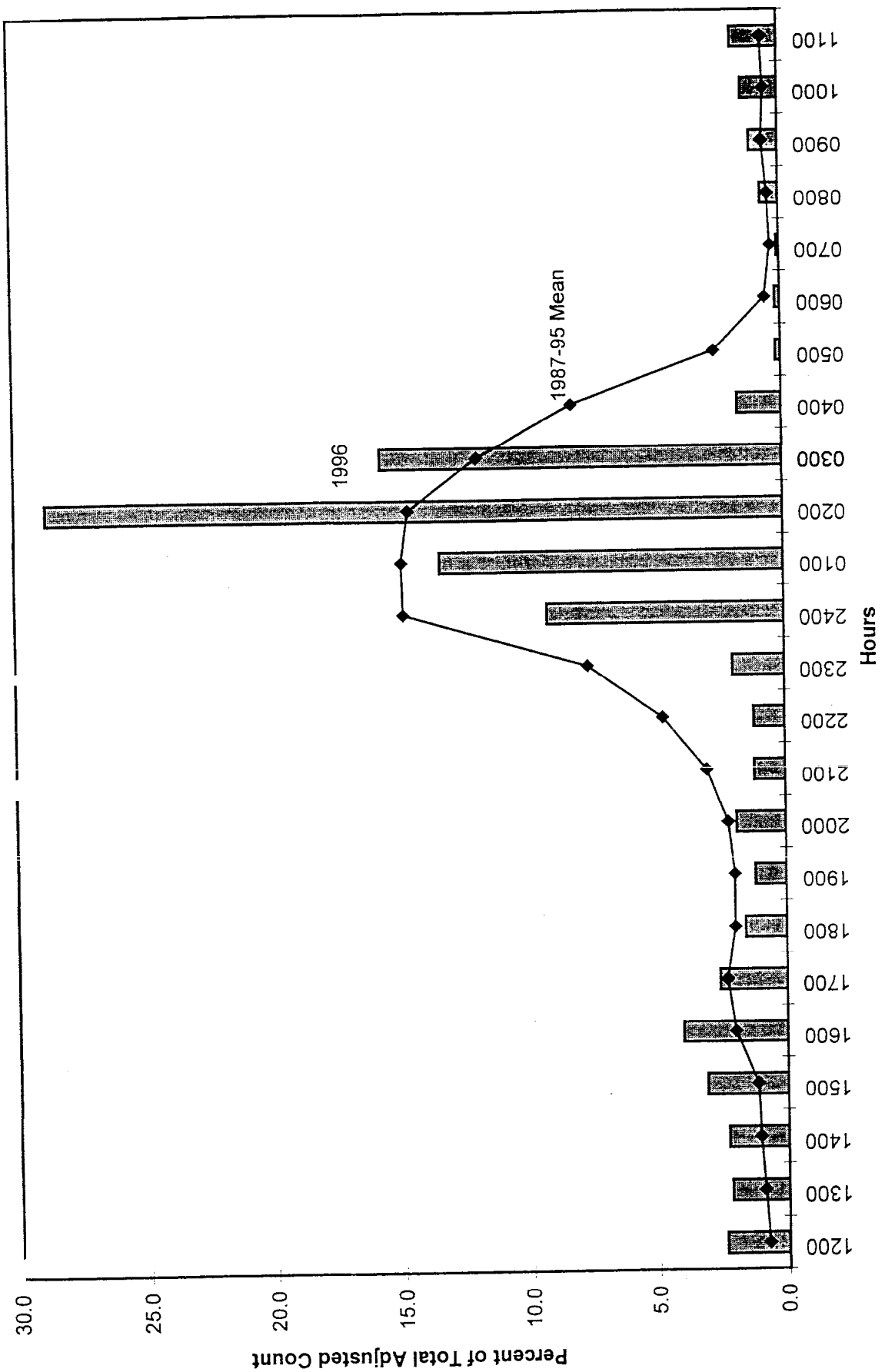
Appendix F.9. Scatter plot of 1996 Ugashik River smolt fyke net catch per unit effort (CPUE) data versus corresponding hourly sonar counts.



Appendix F.10. Comparison of the 1996 Ugashik River smolt sonar count, percent of total adjusted sonar count by smolt day, with the 1987-1995 mean.



Appendix F.11. Comparison of the 1996 Ugashik River smolt sonar count, cumulative percent of total adjusted sonar count by smolt day, with the 1987-1995 mean.

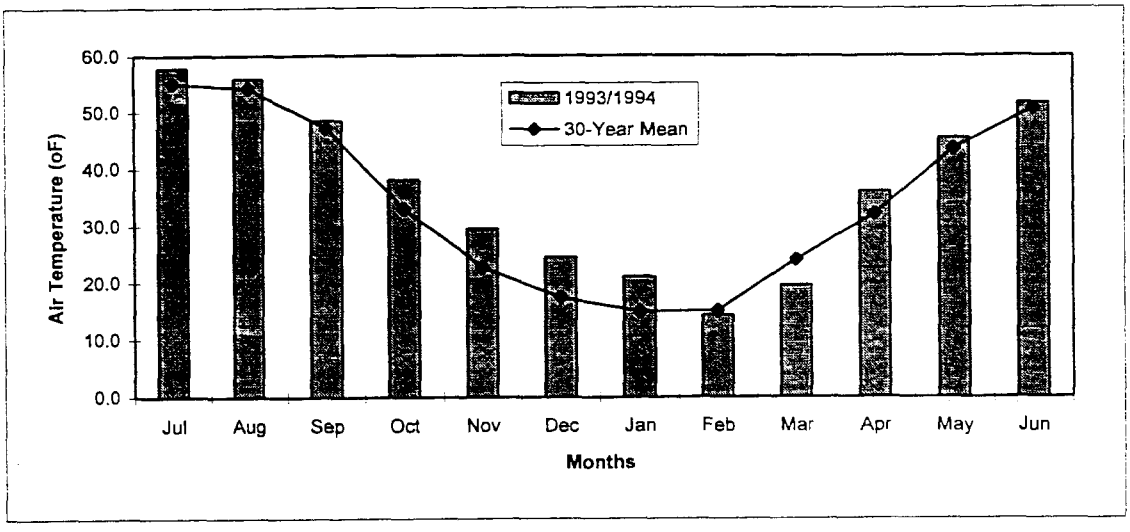


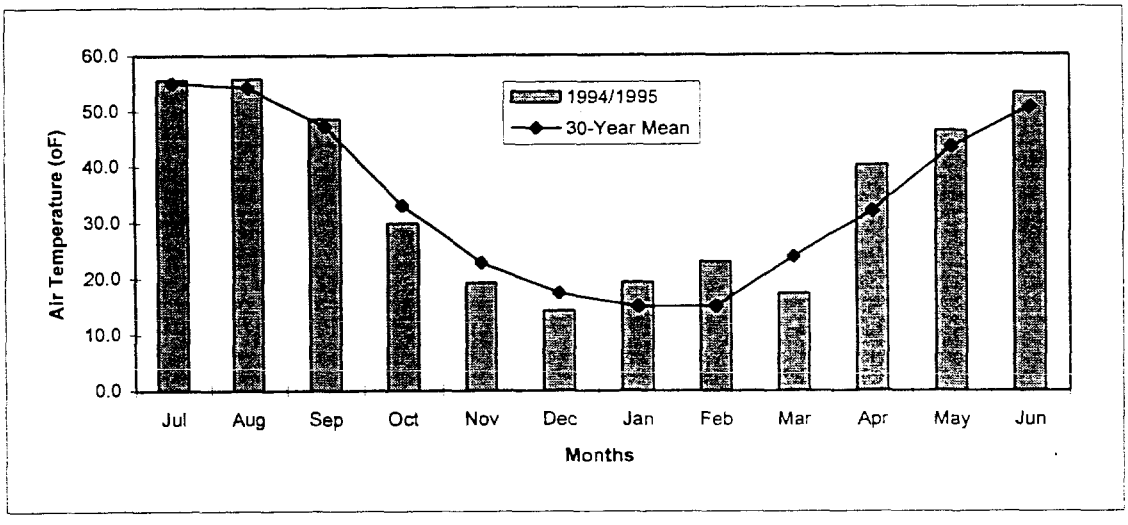
Appendix F.12. Comparison of the 1996 Ugashik River smolt sonar count, percent of total adjusted sonar count by hour, with the 1987-1995 mean.

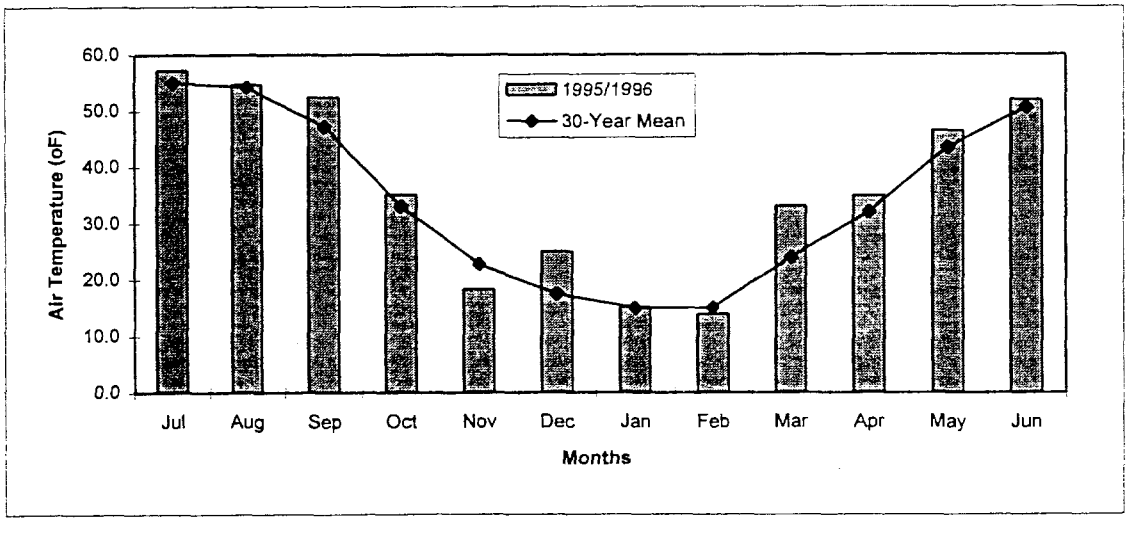
Appendix F.13. Average monthly air temperature for King Salmon, July 1966 to June 1996.

Smolt Year	Air Temperature (°F) [a]												Average Annual
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
1966-67	52.6	50.2	47.0	27.2	20.5	8.9	7.6	15.0	26.6	34.6	44.0	50.6	32.1
1967-68	54.6	54.6	46.3	30.0	29.3	12.0	10.0	12.8	25.5	30.1	43.8	50.7	33.3
1968-69	55.5	54.6	43.3	28.4	26.2	3.4	6.9	12.8	26.3	34.4	44.1	52.5	32.4
1969-70	54.3	50.9	48.1	38.8	17.0	26.2	-0.3	26.4	30.5	29.8	44.8	51.1	34.8
1970-71	52.7	51.7	44.8	29.3	29.3	11.6	-2.6	12.2	7.8	26.8	37.7	47.3	29.1
1971-72	54.5	54.9	46.8	34.3	21.6	18.6	6.7	6.2	1.8	2.1	40.9	46.6	27.9
1972-73	55.2	54.4	45.5	36.0	25.4	16.2	1.8	19.5	19.3	35.9	42.9	51.4	33.6
1973-74	55.6	54.6	47.2	34.1	24.7	17.9	9.5	0.4	23.2	35.6	45.5	51.2	33.3
1974-75	55.4	57.0	50.6	33.4	20.1	8.0	4.7	3.9	14.5	25.0	39.4	47.1	29.9
1975-76	54.7	53.6	47.1	32.4	12.7	10.2	12.3	7.3	15.3	29.5	39.5	46.9	30.1
1976-77	53.2	53.1	45.3	31.5	24.2	19.3	34.4	30.1	18.8	25.7	39.5	50.5	35.5
1977-78	54.3	56.8	47.0	31.7	14.1	10.6	28.6	24.8	25.6	37.5	45.2	49.5	35.5
1978-79	54.2	57.1	47.7	36.5	30.0	28.0	30.1	6.2	30.3	39.6	47.3	52.0	38.3
1979-80	57.8	56.0	50.0	39.4	29.4	4.5	9.0	20.7	27.6	36.4	41.7	48.9	35.1
1980-81	55.1	51.1	47.0	35.2	26.3	5.3	29.8	21.9	34.4	35.8	46.8	50.3	36.6
1981-82	55.1	54.8	44.9	33.2	23.4	13.3	17.0	12.8	23.9	25.5	40.3	48.9	32.8
1982-83	51.5	52.3	46.2	28.1	26.1	24.0	11.9	18.7	33.2	36.5	46.6	53.8	35.7
1983-84	57.4	54.1	45.5	28.8	30.1	27.2	17.4	-2.1	36.3	29.2	43.0	52.3	34.9
1984-85	53.7	53.5	48.0	30.1	22.5	24.7	32.6	10.6	22.6	20.8	39.9	47.4	33.9
1985-86	54.3	52.4	47.4	26.7	25.1	34.2	16.9	22.1	21.5	28.1	42.1	49.9	35.1
1986-87	53.7	52.2	48.8	36.1	26.3	30.6	21.1	24.3	29.8	32.3	42.8	49.3	37.3
1987-88	55.9	57.0	45.4	37.5	16.5	9.4	25.6	26.6	24.8	31.1	44.5	52.8	35.6
1988-89	56.8	53.5	45.8	30.9	13.9	20.8	-2.9	28.8	23.6	36.1	42.0	51.6	33.4
1989-90	56.3	57.1	51.7	36.7	18.1	19.5	16.8	-1.8	25.4	39.3	45.8	51.4	34.7
1990-91	56.0	55.9	47.5	31.5	17.3	20.4	17.5	14.2	25.7	36.4	44.5	50.4	34.8
1991-92	55.2	53.7	50.7	37.2	23.1	15.1	17.7	3.1	22.0	32.4	42.7	52.6	33.8
1992-93	55.6	53.9	41.0	31.7	23.5	19.2	15.0	22.7	31.1	41.0	48.3	53.1	36.3
1993-94	57.9	56.0	48.6	38.1	29.6	24.6	21.2	14.3	19.5	36.0	45.4	51.7	36.9
1994-95	55.7	55.9	48.6	29.9	19.3	14.3	19.5	23.1	17.4	40.3	46.4	53.2	35.3
1995-96	57.3	54.8	52.5	35.1	18.4	25.0	15.2	14.0	33.1	34.9	46.5	52.0	36.6
Max	57.9	57.1	52.5	39.4	30.1	34.2	34.4	30.1	36.3	41.0	48.3	53.8	38.3
Avg	55.1	54.3	47.2	33.0	22.8	17.4	15.0	15.1	23.9	32.0	43.5	50.6	34.1
Min	51.5	50.2	41.0	26.7	12.7	3.4	-2.9	-2.1	1.8	2.1	37.7	46.6	27.9

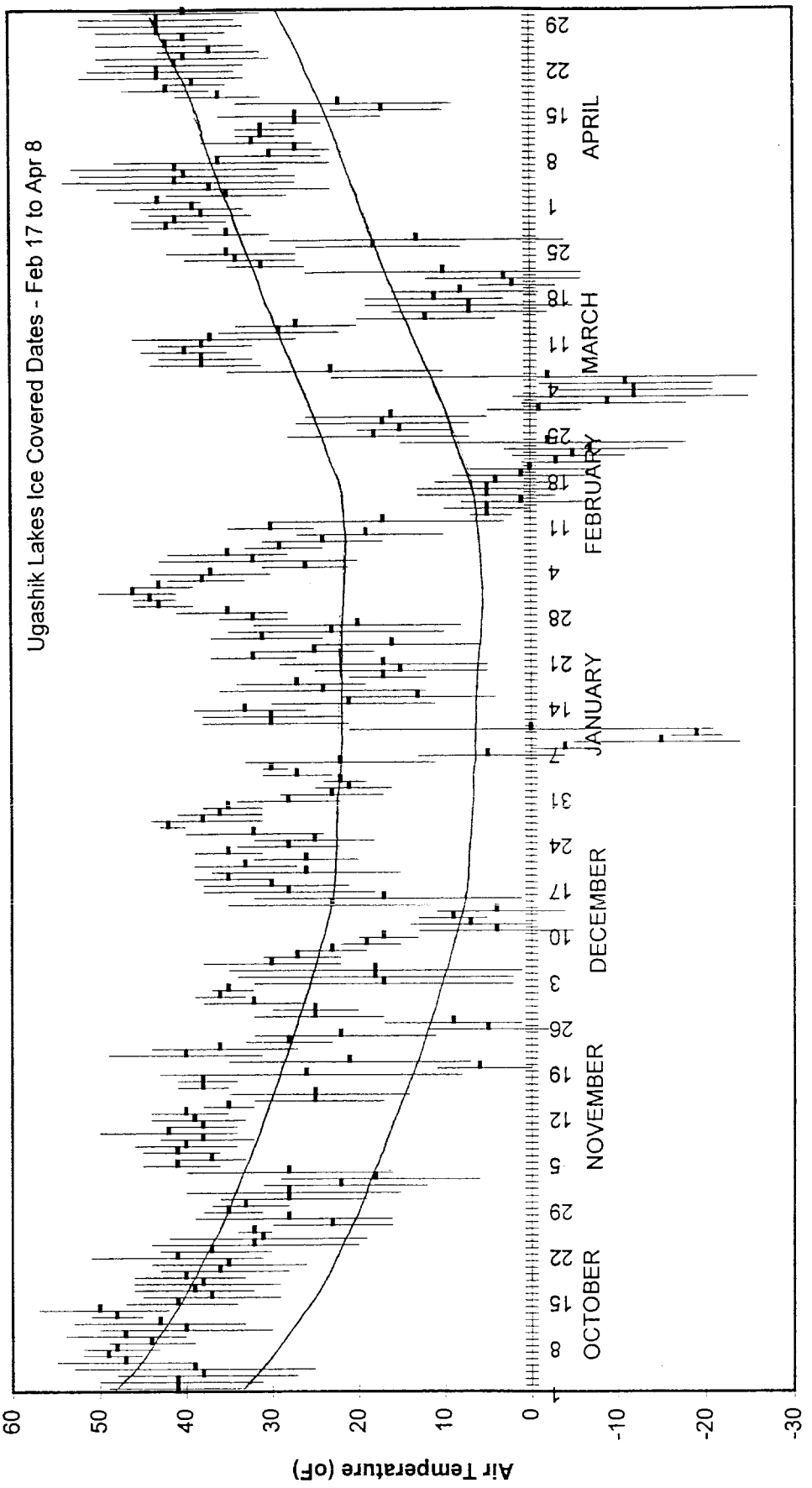
[a] Source - National Weather Service (1995; 1996a,b,c,d,e,f)



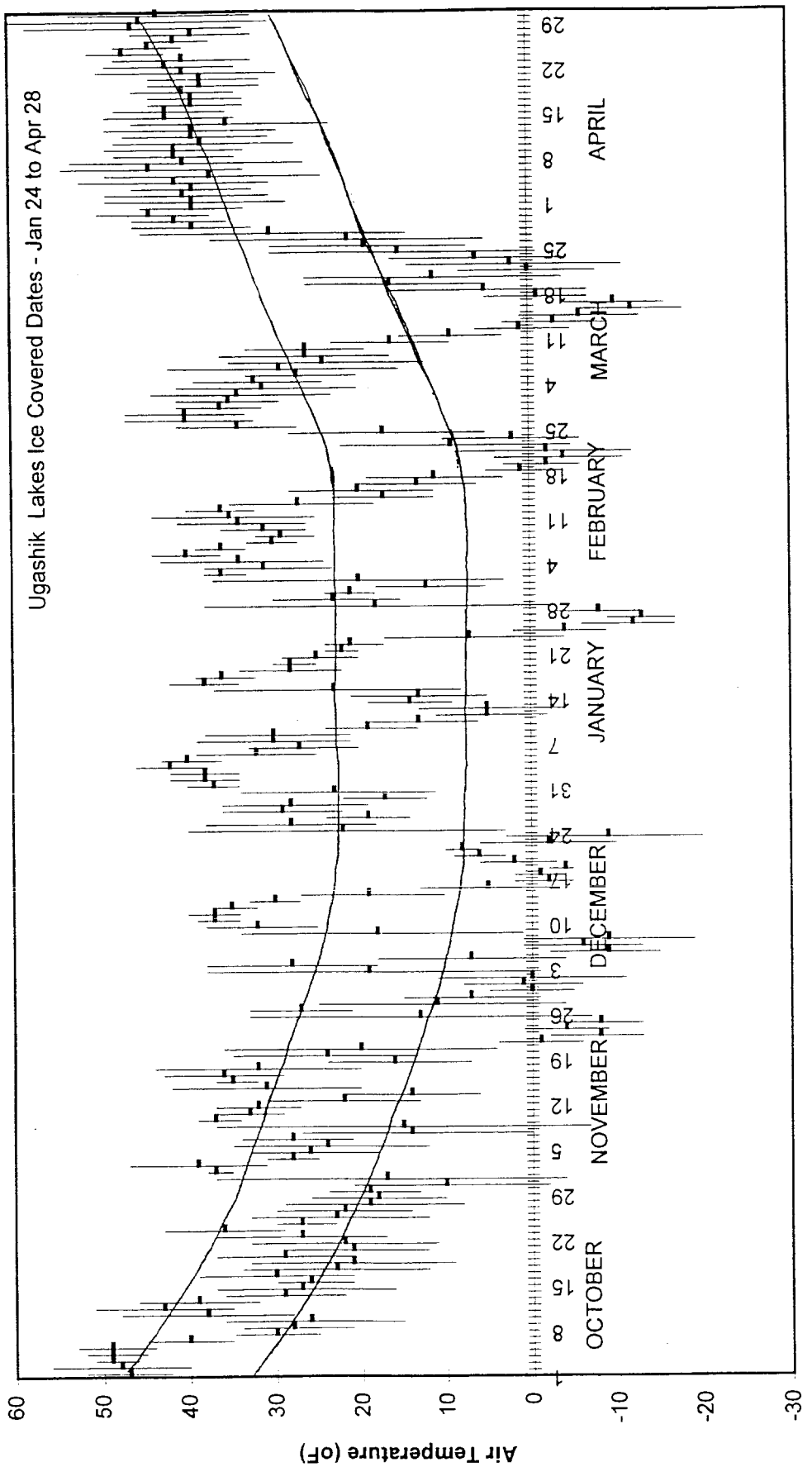




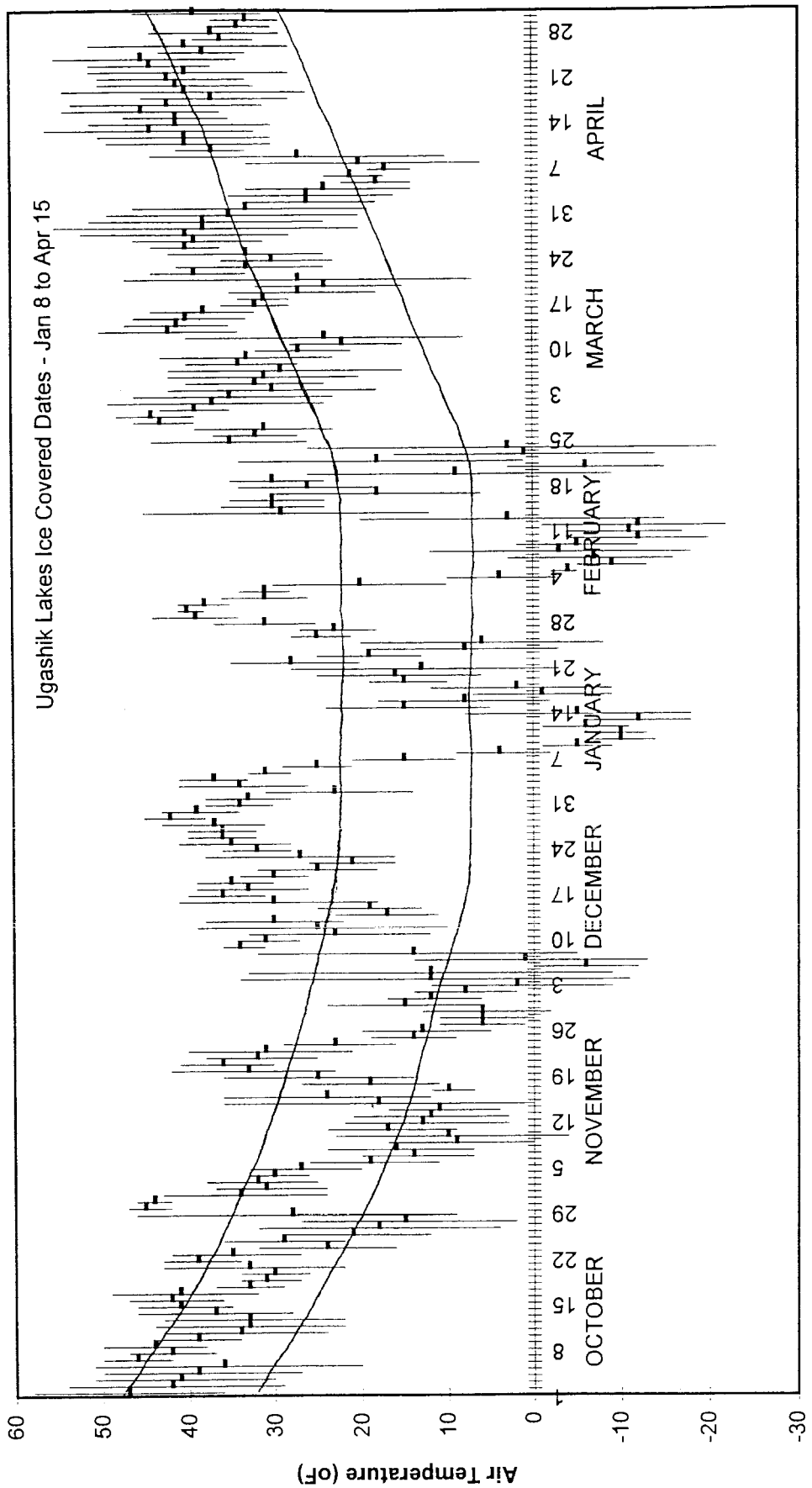
Appendix F.14. Comparision of monthly air temperature to the 30-year mean at King Salmon, July 1993 to June 1996.



Appendix F.15. Daily air temperatures (normals, means and extremes) for King Salmon, October 1993 to April 1994.



Appendix F.16. Daily air temperatures (normals, means and extremes) for King Salmon, October 1994 to April 1995.

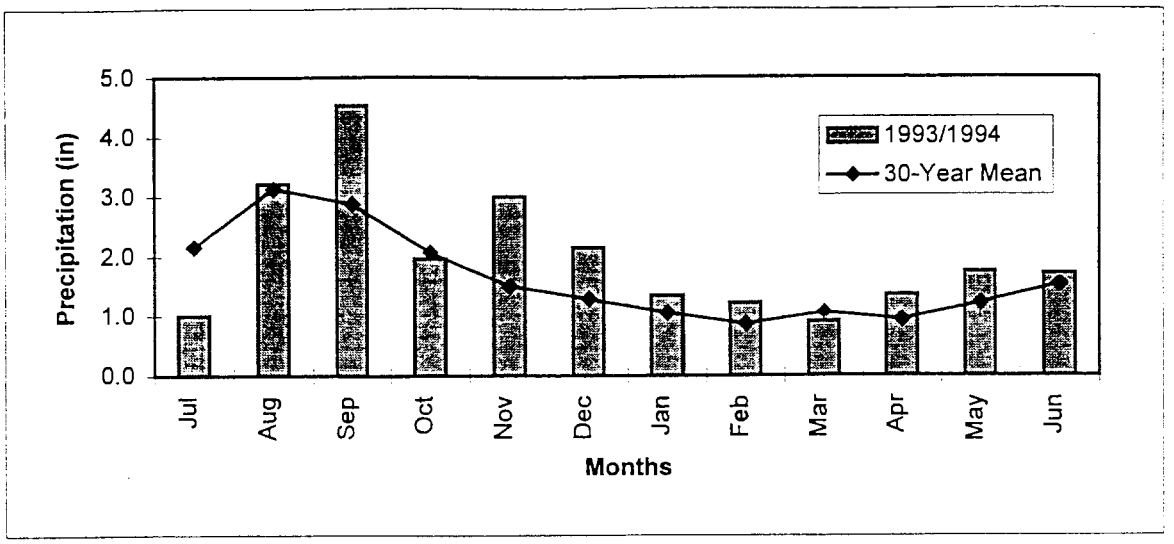


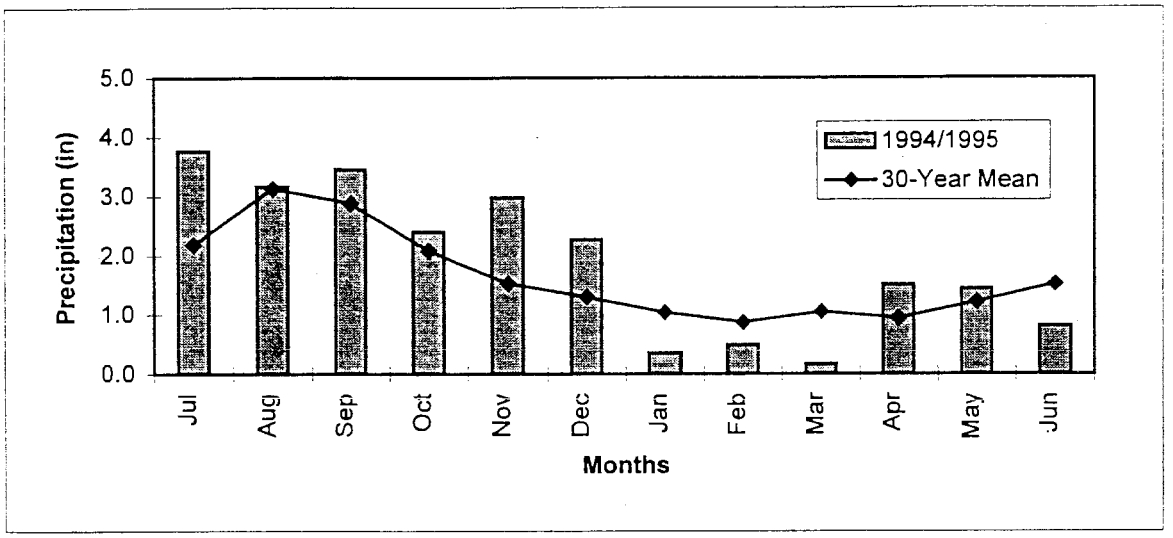
Appendix F.17. Daily air temperatures (normals, means and extremes) for King Salmon, October 1995 to April 1996.

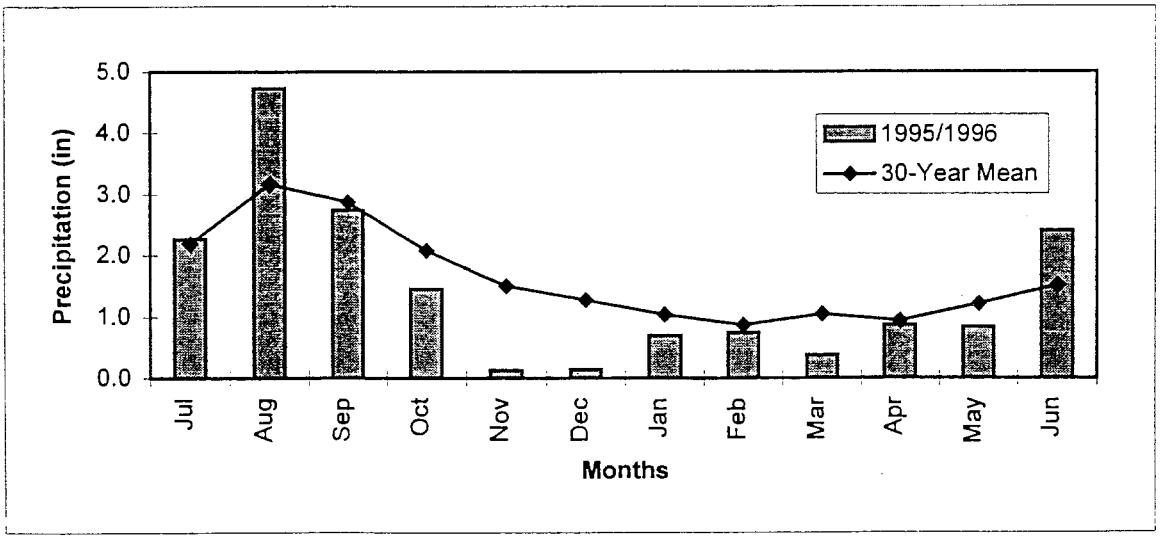
Appendix F.18. Average monthly precipitation for King Salmon, July 1966 to June 1996.

Smolt Year	Precipitation (in) [a]												Total Annual
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
1966-67	2.45	5.69	3.73	2.88	2.17	0.54	0.93	0.54	2.41	1.33	0.22	2.90	25.79
1967-68	3.15	3.15	1.69	0.52	1.90	2.03	1.10	0.57	0.80	1.41	1.26	1.35	18.93
1968-69	1.14	2.20	2.70	0.51	0.91	1.25	0.65	1.94	1.19	0.30	0.79	0.56	14.14
1969-70	2.19	3.42	1.28	2.33	1.84	0.57	0.50	0.45	1.81	1.80	0.41	1.13	17.73
1970-71	2.87	4.31	1.59	2.24	0.79	1.33	0.45	1.62	0.27	0.84	1.43	1.48	19.22
1971-72	3.25	4.30	3.40	2.72	1.13	3.42	1.30	0.21	0.17	1.37	1.29	1.62	24.18
1972-73	1.08	1.95	2.95	2.57	1.35	0.59	0.62	0.11	1.25	0.43	1.83	1.48	16.21
1973-74	2.43	3.80	1.41	1.52	0.97	1.10	0.86	0.55	1.27	1.18	0.57	2.40	18.06
1974-75	2.01	3.19	1.56	2.90	1.20	1.23	2.14	0.76	0.93	2.65	0.86	2.69	22.12
1975-76	0.74	1.05	3.90	2.10	0.46	1.38	1.24	0.97	0.78	0.58	1.47	1.34	16.01
1976-77	2.60	1.71	2.64	0.81	2.06	1.77	0.85	1.35	1.99	1.68	1.72	0.99	20.17
1977-78	1.60	3.16	2.58	3.29	0.58	1.04	0.70	0.28	0.26	0.58	0.98	2.81	17.86
1978-79	1.66	2.03	1.87	2.84	1.77	3.65	1.00	0.29	0.39	1.20	0.46	1.80	18.96
1979-80	2.24	2.50	0.91	2.71	2.89	1.09	1.46	0.83	1.51	0.42	1.61	2.19	20.36
1980-81	2.97	2.36	2.00	2.46	1.19	0.49	1.76	2.26	1.83	0.49	0.73	2.27	20.81
1981-82	2.17	3.93	1.82	1.59	1.31	0.59	1.48	0.15	1.37	1.20	1.55	3.04	20.20
1982-83	1.98	1.99	5.14	1.41	0.83	1.37	0.42	0.25	0.22	2.22	1.37	1.20	18.40
1983-84	1.53	2.33	2.36	2.82	0.98	0.48	1.17	0.55	0.44	0.43	1.08	1.59	15.76
1984-85	1.30	2.41	0.89	0.57	1.00	1.79	0.95	0.73	1.27	0.34	1.16	1.23	13.64
1985-86	1.31	3.24	2.64	2.29	3.35	1.58	1.33	0.19	0.24	0.98	1.01	0.93	19.09
1986-87	2.44	3.22	4.03	2.50	1.91	0.65	2.38	0.54	0.55	0.81	1.74	1.49	22.26
1987-88	1.94	2.73	2.99	2.47	2.75	1.07	0.56	0.75	0.74	1.02	2.95	1.11	21.08
1988-89	2.73	2.88	2.17	1.68	1.52	1.60	0.84	0.93	0.19	0.99	2.32	1.10	18.95
1989-90	3.04	3.15	5.90	2.86	1.58	1.31	1.44	1.61	1.71	0.89	1.52	1.22	26.23
1990-91	5.08	2.02	2.75	2.38	2.10	3.26	0.55	0.58	1.56	0.86	1.24	1.63	24.01
1991-92	1.02	1.79	2.10	1.99	1.34	1.26	0.79	0.92	1.40	0.19	0.74	2.53	16.07
1992-93	3.02	4.73	1.35	1.11	1.45	1.77	1.48	0.35	0.26	0.50	0.70	0.50	17.22
1993-94	1.01	3.21	4.53	1.98	3.00	2.15	1.35	1.22	0.91	1.35	1.74	1.71	24.16
1994-95	3.77	3.17	3.46	2.41	2.98	2.28	0.35	0.49	0.17	1.51	1.44	0.81	22.84
1995-96	2.27	4.73	2.74	1.46	0.13	0.14	0.70	0.75	0.38	0.87	0.84	2.41	17.42
Max	5.08	5.69	5.90	3.29	3.35	3.65	2.38	2.26	2.41	2.65	2.95	3.04	26.23
Avg	2.23	3.01	2.64	2.06	1.58	1.43	1.05	0.76	0.94	1.01	1.23	1.65	19.60
Min	0.74	1.05	0.89	0.51	0.13	0.14	0.35	0.11	0.17	0.19	0.22	0.50	13.64

[a] Source - National Weather Service (1995; 1996a,b,c,d,e,f)







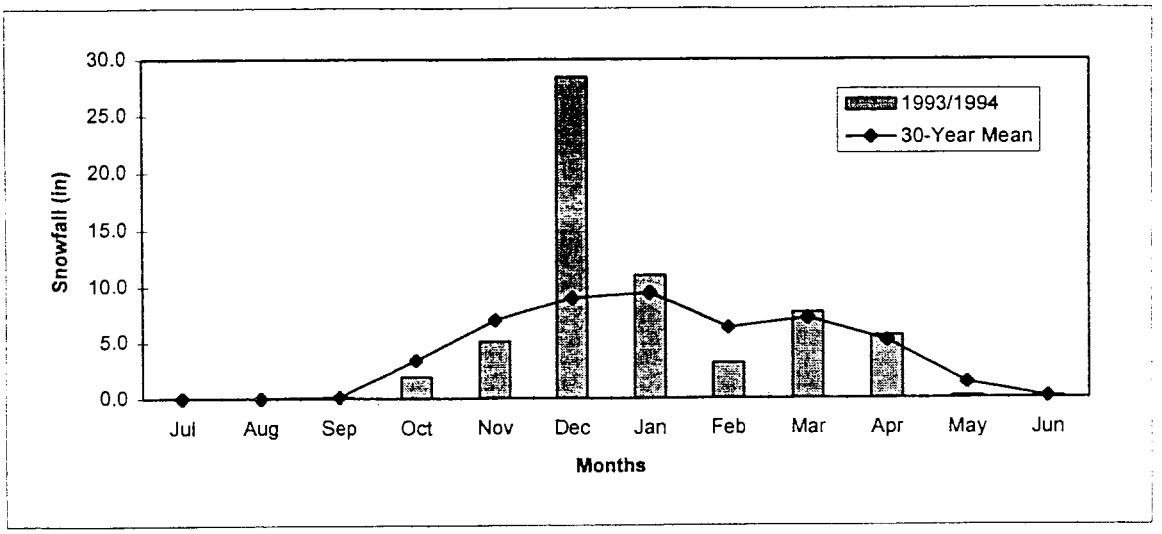
Appendix F.19. Comparision of monthly precipitation to the 30-year mean at King Salmon, July 1993 to June 1996.

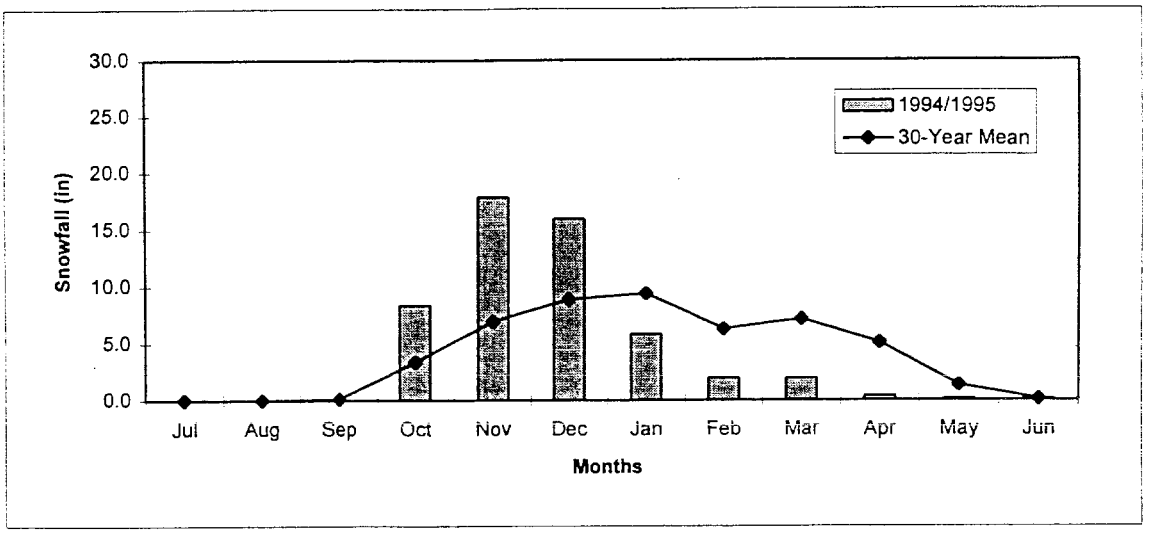
Appendix F.20. Average monthly snowfall for King Salmon, July 1966 to June 1996.

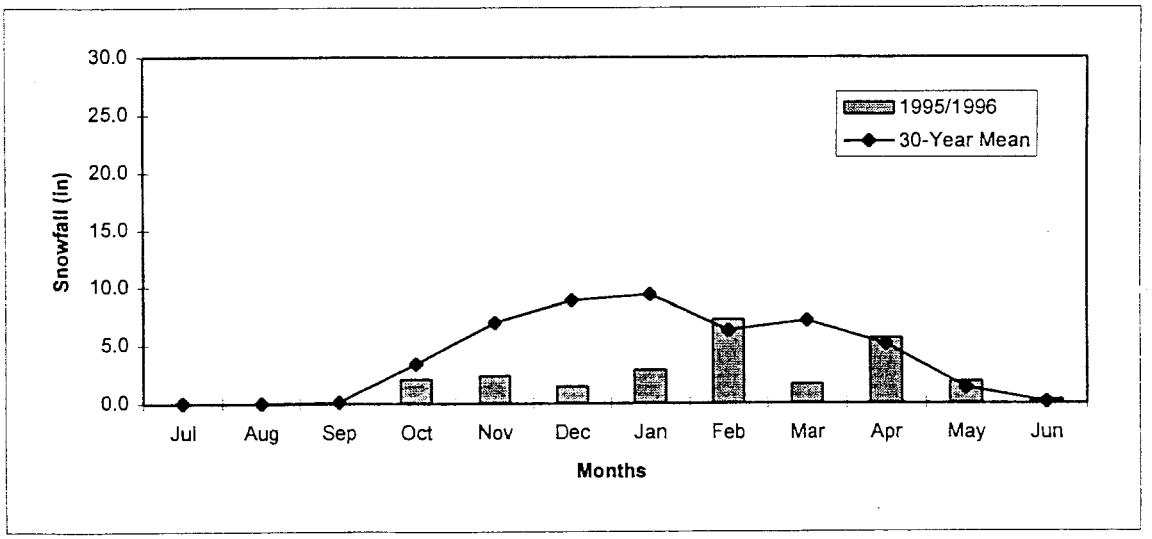
Smolt Year	Snowfall (in) [a b]												
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total Annual
1966-67	0.0	0.0	0.0	5.3	8.1	6.1	7.7	5.1	5.7	2.9	0.0	0.0	40.9
1967-68	0.0	0.0	0.0	1.2	4.1	3.5	9.3	5.3	7.5	16.0	2.2	0.0	49.1
1968-69	0.0	0.0	0.3	0.3	8.9	10.8	6.1	13.9	12.3	1.1	T	0.0	53.7
1969-70	0.0	0.0	0.0	T	16.1	1.5	11.1	4.6	6.4	5.5	T	0.0	45.2
1970-71	0.0	0.0	T	8.3	1.4	8.6	4.3	15.2	1.6	8.9	2.5	T	50.8
1971-72	0.0	0.0	0.0	7.9	3.9	15.1	11.7	2.1	1.9	8.7	0.1	1.3	52.7
1972-73	0.0	0.0	T	0.8	8.0	2.1	3.0	0.8	8.1	2.2	0.6	0.0	25.6
1973-74	0.0	0.0	T	2.0	2.1	12.7	11.9	5.3	4.6	5.1	T	0.0	43.7
1974-75	0.0	0.0	0.0	T	4.3	10.9	19.1	6.3	8.7	14.3	2.9	0.0	66.5
1975-76	0.0	0.0	0.0	0.8	3.9	13.9	12.0	3.2	6.7	6.2	3.2	0.0	49.9
1976-77	0.0	0.0	0.0	2.0	10.9	11.0	2.1	11.9	20.0	4.6	T	0.0	62.5
1977-78	0.0	0.0	T	4.3	5.3	4.5	3.9	3.7	2.2	0.6	T	0.0	24.5
1978-79	0.0	0.0	0.0	1.0	2.2	14.1	4.4	0.2	1.1	T	T	0.0	23.0
1979-80	0.0	0.0	0.0	T	8.5	9.7	11.5	11.1	9.0	T	0.8	0.0	50.6
1980-81	0.0	0.0	0.0	0.3	6.1	6.8	10.5	11.3	15.8	0.6	T	T	51.4
1981-82	0.0	0.0	0.5	0.3	4.8	5.9	5.7	T	8.3	8.3	T	0.0	33.8
1982-83	0.0	0.0	0.0	2.8	2.0	2.9	4.0	2.0	T	6.0	0.1	0.0	19.8
1983-84	0.0	0.0	T	9.9	2.3	2.8	8.4	5.5	T	4.0	0.3	0.0	33.2
1984-85	0.0	0.0	0.0	3.4	7.3	3.8	3.7	6.4	8.9	3.4	6.1	0.0	43.0
1985-86	0.0	0.0	0.0	2.5	9.3	3.6	13.5	1.8	2.5	9.8	1.3	0.0	44.3
1986-87	0.0	0.0	0.0	2.3	2.5	4.8	24.7	2.7	2.7	9.4	T	0.0	49.1
1987-88	0.0	0.0	T	0.1	13.2	8.9	3.3	10.1	9.4	4.4	1.2	0.0	50.6
1988-89	0.0	0.0	T	3.4	12.7	9.2	14.9	3.7	5.1	1.5	2.1	0.0	52.6
1989-90	0.0	0.0	T	0.4	12.3	12.4	14.9	20.3	13.5	3.4	0.2	0.0	77.4
1990-91	0.0	0.0	T	15.7	6.7	18.9	3.1	4.3	14.0	2.8	0.0	0.0	65.5
1991-92	0.0	0.0	0.0	T	9.0	9.4	7.2	8.6	8.7	0.5	T	T	43.4
1992-93	0.0	0.0	T	0.9	7.9	8.0	30.6	5.5	5.2	1.8	T	T	59.9
1993/1994	0.0	0.0	0.1	2.0	5.1	28.4	11.0	3.2	7.7	5.6	0.2	0.1	63.4
1994/1995	0.0	0.0	0.0	8.4	17.9	16.0	5.9	2.0	2.0	0.4	0.1	0.1	52.8
1995/1996	0.0	0.0	0.0	2.1	2.4	1.5	2.9	7.3	1.7	5.7	1.9	0.3	25.8
Max	0.0	0.0	0.5	15.7	17.9	28.4	30.6	20.3	20.0	16.0	6.1	1.3	77.4
30-Year Mean	0.0	0.0	0.1	3.4	7.0	8.9	9.4	6.3	7.2	5.1	1.4	0.1	46.8
Min	0.0	0.0	0.0	0.1	1.4	1.5	2.1	0.2	1.1	0.4	0.0	0.0	19.8

[a] Source - National Weather Service (1995; 1996a,b,c,d,e,f)

[b] T = trace







Appendix F.21. Comparision of monthly snowfall to the 30-year mean at King Salmon, July 1993 to June 1996.